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COLLECTION AND DISPOSAL
OF
MUNICIPAL REFUSE

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OF
MUNICIPAL REFUSE

BY

RUDOLPH HERING, D.Sc.

NEW YORK CITY

Past President of American Public Health Association and of Engineers Club of Philadelphia; Past Vice-President of American Society of Civil Engineers. Member of American Institute of Consulting Engineers; American Society of Mechanical Engineers; Institution of Civil Engineers, London; Engineering Institute of Canada; Western Society of Engineers, etc.

AND

SAMUEL A. GREELEY

CHICAGO, ILL.

Member of American Public Health Association, American Society of Civil Engineers, Western Society of Engineers, American Association of Engineers, American Water Works Association, Illinois Society of Engineers, etc.

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PREFACE

The purpose of this book is to record and discuss the various experiences in the disposition of municipal refuse. Other books have been written on this subject, or on parts of it, as in the United States by Morse, by Parsons, and by Venable; and in England by Maxwell and by Goodrich; but there seemed to be room for a more comprehensive survey of the subject in the light of later experiences. There also seemed to be a need for stating more fully than done heretofore the fundamental principles relating to house treatment, collection, and final disposal. Such statements may be helpful, particularly as private interests sometimes compete with public interests, and as both should be identical when considering the general benefits to the community.

The present book has been in hand for the last ten years, at intervals between other engineering work, and has required more labor, correspondence, inspection, inquiry, and consideration than was anticipated. This was due mainly to the desire of the authors to offer, not only a record of general principles, but also of present practice resulting from experience, so that it might be helpful to both designing and operating engineers, in securing efficiency and economy in a branch of public service which in America is still undergoing development, principally in methods of disposal.

The information presented has been verified as far as practicable. Although many data were estimated, or averaged, and some are based only on judgment, it is hoped that their inclusion may still be of service, and be the means of encouraging the collection and recording of more accurate statistics. Some of the information in city reports has little meaning to outsiders, mainly because it is not reduced to unit measures, such as quantities per capita per annum, etc., and to those which are independent of wages, population, and variable bases. Therefore, such reports do not allow of comparison with data reported from other cities, and do not show the relative effects of local conditions. In some cases we have added reductions

to unit terms, and in others the reader may himself be able to make them for special cases.

Some of the information was selected chiefly for illustration, and was not intended to be applicable at present. Occasionally, also, the data for certain cities are apparently inconsistent, but the authorities, where available, have been cited, as it was thought that this would indicate the importance of reporting more completely the conditions affecting the given figures, and thereby indicate also the variations in the treatment which may occur under different local conditions of time and place.

To have collated all detailed information concerning existing works that might have been of interest was not attempted. Yet, enough has been given, it is hoped, to enable the reader or the designer of any special work to obtain general ideas, make better comparisons, and form safe general opinions on the subject. If more detailed information is desired for a specific purpose, this can probably be best obtained by direct correspondence with the respective city officials.

The data in the book have been selected partly from original sources, and partly from publications, articles, and reports. In numerous tables the figures for some of the years have been omitted, partly because they were not readily available, and partly to reduce space. Generally, the years of most value in assisting judgment as to quantities and cost have been selected, as, for instance, just before, during, and after the War.

Some of the tabular matter has been given as it was received, and some has been rearranged, condensed, and extended, for greater usefulness.

Lack of consistency in the use of terms is sometimes apparent in quotations from different authors.

In a few instances, and for greater convenience of reference and use, there are some slight repetitions in the text. On the other hand, to avoid repetition, general historical information is given only in the introduction, and that relating chiefly to special developments is included only in the respective chapters.

In order to make the cost data as useful as possible, the years (approximately) to which they are applicable have been given. Most of them relate to conditions before the War. To use these with safety, it will be necessary to obtain for each locality the percentage of increase in the wages, and in the cost of materials, and to apply the corrections to the pre-war prices.

In order to facilitate the preparation of specifications for the letting of contracts, there have been added some quotations and abstracts from specifications which have stood the test of experience,

and some suggestions which may be of further service, but these are limited to the most important items. Conditions of locality vary so greatly that no single form will suit all. From what is herein stated, the local engineer can readily supplement the engineering parts and the local attorney draw up the legal parts.

The technical terms that apply specially to the subject of municipal refuse and have been used by us are defined in the text. A few available sample cards of rules and regulations for house treatment have been given. Undoubtedly there are sets of regulations in other cities that would be equally helpful guides.

The authors desire to express their acknowledgments and give credit and thanks to the municipal officers, city engineers, firms, personal friends, and others, who had special experience in the branches of this subject and provided much of the information embodied in this book. Among those to whom it is desired to give special mention are the following:

For a number of illustrations we are indebted to various cities, firms, and individuals: to Mr. H. de B. Parsons, who kindly loaned some electrotypes; and to Mr. W. F. Morse, and Mr. W. F. Goodrich, for published illustrations of earlier incinerators. Mr. W. W. DeBerard and Mr. John Primrose kindly read over parts of the original manuscript.

We are also indebted for information obtained from numerous city reports and from the Engineering Press for various descriptions and illustrations relating to present-day practice, and to manufactures and others; particularly to J. T. Fetherston, E. H. Foster, and R. W. Parlin, Members, American Society of Civil Engineers, and also Professor Frederic Bonnet, Jr., who has supplied suggestions and specific information. Lastly, we desire to mention the assistance we have received from time to time from members of Mr. Greeley's staff: Messrs. Robert A. Allton, R. S. Rankin, W. T. McClenahan, and Wm. E. Stanley, and in particular the valuable services of Mr. T. J. McMinn, past Assistant Secretary, American Society of Civil Engineers, in revising the manuscript and the tabular matter, in preparing the index, and assisting in the editorial work. We also desire to thank the publishers for the creditable manner in which they have issued the book, so as to facilitate its use.

Rudolph Hering,
Samuel A. Greeley.

New York and Chicago,
December, 1920.

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COLLECTION AND DISPOSAL OF MUNICIPAL REFUSE

INTRODUCTION

As the human race evolved, and nomadic tribes settled down in permanent abodes to form communities, the disposition of their rejected materials began to require special attention. It is recorded that Moses enjoined his people to carry all offensive and unclean matter outside of the camp and burn it. Garbage was thrown out on the fields, as still done in parts of Asia to-day, to be eaten by dogs or buzzards. All non-decomposable and inoffensive waste was usually thrown on low areas or on the roads. Some of the streets in the oldest European cities have been gradually raised several feet by the rubbish dumped on them during centuries.

The rapid growth of modern cities, particularly since the development of sanitary science had mastered the problems of water supply and sewerage, brought the refuse removal problem also into prominence. England led this progressive movement in starting works for such removal and disposal in its cities and towns. Germany followed, and advanced the subject in essential directions by its proverbial thoroughness in both theory and practice. France also followed the advance, and was interested chiefly in utilizing the valuable parts of the refuse.

America then took up the above experiences and, while trying most of the European methods, developed others, made possible by the greater wastefulness of its people and consequently by a greater per capita production of salable refuse.

The older cities of Europe were obliged to solve these problems satisfactorily before they had seriously presented themselves in America. Europe therefore has gained much experience, a high degree of efficiency and economy, and has arrived at conclusions which are helpful also to us. The authors, therefore, inspected many European works, and studied municipal reports and publications. To a much greater extent, however, they have done this in America. It is therefore hoped that the presentation of the combined experiences gained on both continents may assist American municipalities in reaching the best solutions.

Although our conditions differ in many respects from those common in Europe, we must, nevertheless, be aware of the fact that some European cities have passed through conditions similar to some of ours, and in conducting municipal affairs have at present arrived at solutions which in time we may also find best to adopt, although as yet we may only be beginning to approach them.

The recent development in America started in 1887, by the American Public Health Association, with the appointment of a Committee on Garbage Disposal, of which Dr. Kilvington was Chairman. In 1888, this Committee reported on the "Destruction of Organic Refuse by Fire." In 1889, a report was presented favoring both reduction and incineration as the promising methods of future garbage disposal. In 1894, Rudolph Hering was appointed Chairman, elaborate statistics were collected from more than a hundred cities, and in 1897 a report was made on the collection and disposal of waste matter in many of those cities, with general conclusions regarding the entire problem. A great diversity of opinion was observed regarding the proper methods to be pursued. The Committee also studied the English experiences and the very complete, instructive, and valuable experiments just then being conducted in Hamburg and Berlin, and presented conclusions which endeavored to place the whole subject on a scientific foundation.

The sanitary aspect was given the first and the financial aspect the second place in all recommendations. It was pointed out that a proper solution for any city or town would require a knowledge of the quantity, character, and composition of the refuse, and also of the local conditions controlling the several parts of the problem.

As to the methods of final disposal, the report recommended, as complying best with the sanitary requirements under the different local conditions in the United States, the following: "Feeding to swine, dumping on land or into large volumes of flowing water, plowing into soil, extracting grease, or cremating the organic matter." As to the method to be preferred for a given city, it was recommended that from among these sanitary methods, that one should be selected which could be carried out at the least expense, when considering jointly the costs of both construction and operation.

In 1901 Mr. M. N. Baker * stated:

"In no branch of municipal service has so little progress been made in the United States as in the disposal of garbage. Why do such conditions exist? First, because the sanitary collection and disposal is appreciated neither by the general public nor the city officials; second, because it is seldom recognized that the problems incident to final disposal are largely engineering in character and therefore should be entrusted to engineers."

* "The Unsatisfactory Condition of Garbage Disposal in the United States." Paper read before the League of American Municipalities, 1901.

Since then much progress has been made, not only in a better appreciation of the subject, but also in collating data of experience. First, as regards quantity, we have gained considerable knowledge from records compiled, even when approximate, so that the selection of more rational and economical means of collection and disposal have gradually become practicable. Secondly, as regards quality, we have gained some knowledge of the moisture, grease, fertilizing and combustible matter, and also of recoverable and salable materials, contained in refuse. Thirdly, we have secured information regarding the actual practice and cost of collecting the refuse and of disposing of it in practicable ways.

The fundamental parts of the problem have also been gradually developed, particularly by realizing the necessity of a more intimate co-operation of the householder with the collection part of the problem. House treatment, therefore, has been given greater attention than heretofore.

All needed information leading to a complete knowledge of these subjects is not yet available, and particularly has the recent economical disturbance, caused by the War, affected not only the cost, but also the quantities and qualities of the waste materials themselves, so that at present the conclusions reached may sometimes differ from those that were found to be best just before the War. Therefore, some difficulties in reaching the best solutions may have again temporarily increased, although it is hoped they will soon be removed by the accumulation of more detailed records of experience.

As the problems are largely technical, the next advance can be accomplished by establishing the best practicable organizations, systematizing the entire work under competent engineering advice and management, with the intimate co-operation of the health officers, and, under carefully drawn ordinances, regulating such community work.

A further advance can be made by obtaining more thorough records for a comparison between contract and permanent city force work, from the standpoints of efficiency and cost. The advantages of city force work in the collection service are annually becoming more and more apparent, as city management becomes better, but there yet remain some exceptions to this conclusion, particularly in smaller towns. The advantages of contract work still exist as to some of the disposal plants, especially in those which require manufacturing and business organizations. Experience, more knowledge, and training of permanent city forces have demonstrated in Europe that operation by the city is more desirable for both branches of the work; and a continuation of records in American cities may eventually show the same tendency. This is due to the great complexity of the work, which, for

the best results, requires a continual adjustment to varying details. It is further due to the fact, recognized in Europe more than here, that whatever money benefits may accrue from municipal work should go to the community, to encourage its own officers and men, rather than to contracting individuals and firms.

The rapid progress made within the last fifteen years in the art of refuse handling leads to the belief that the characteristics of the different methods are now more clearly understood, and that the details can be handled more effectively, than in former years. Therefore, the introduction of still better adjustments in the details of the methods of collection and disposal of municipal refuse now seems assured. This can be accomplished only by having officials better informed and trained, and this will secure better sanitation at less cost. In the light of more investigations and experience, the uncertainties are being reduced, some of the older usages are disappearing, and more efficient and economical ones are taking their places.

As the local conditions of a city sometimes vary greatly, and therefore require different methods and treatment, it is now recognized that a decision as to the proper recommendations for the best solutions of the problem in a city must rest on the result of a prior thorough inquiry into all controlling conditions.

It is also recognized that we should divide the subject into three parts: House treatment, collection, and disposal, and that the details of each are dependent on those of the others. We shall therefore first discuss the ways of preparing at the house the different kinds of refuse for collection, secondly, the ways of collecting, transporting, and delivering them to the points of disposal, and thirdly, the various means for their sanitary disposition, whether separately or combined.

The house treatment rests entirely with the producer of the refuse. Therefore, it is necessary for the community to issue specific rules and regulations, which will guide not only the producer but also the collector in their respective duties at the house, and protect them against troubles that are otherwise apt to arise.

The collection of public refuse is a public utility. It is quite distinct and separate from house treatment and final disposal, although it forms with them an organic whole. Under some conditions the special organization managing it may be a separate one. Although the collection is now often made under contract, chiefly in small communities, it will in the future generally be done more satisfactorily by the city's own forces, because of the greater ease in adjusting details at once to the best sanitary requirements for each special case as it occurs.

The control and management of the final disposal of the refuse in our municipalities at the present time, particularly when it requires a

business organization, may in some cases be conducted under contract as a private affair, as well as, and occasionally even better than, by municipal labor, provided always that it secures equally satisfactory sanitation at a less cost.

The recent war conditions have materially unsettled the rates of wages, and therefore the costs of both labor and materials. As long as such financial uncertainties exist, and in order at all times to maintain a high sanitary standard, safety seems to lie at present on the side of an efficient municipal management and operation of disposal works, where expenditures may be at once adjusted to suddenly arising or extraordinary conditions.

The great changes in prices, and the uncertainties as to their future stability, have made it difficult to give satisfactory statements of costs, necessary as guides in estimating the cost of projected works. We have therefore concluded to record cost items before, during, and after the War, as far as this was practicable. By thus comparing the prices for different years and adjusting them to local experiences and to the prices prevailing at the present time, it is hoped that the repeated statements may be of use.

Never before, as during the last years, has attention been called so strongly to the desirability of having a more rational basis than only the wages of men for estimating the cost of work and materials. Not only do daily wages fluctuate but also the number of hours constituting a working day to which they apply. In times of such economic disturbances it is not possible to foretell the cost as safely as under normal conditions, unless we have a better measure of actual work done. Such measures are those which indicate, irrespective of wages, the efficiency of labor in both time and work elements.

We are quite accustomed to the units of foot-pounds per minute, horse-powers per hour, and ton-miles per hour. Such terms are independent of wages, and have been applied either to animals or engines, but seldom to men. If we had records also of all the various kinds of work which men, skilled and unskilled, can do in one hour, we would then have a measure of actual work pe formed, which would need only to be multiplied by the hourly wage rate, at the time of bidding or estimating, in order to get a rational figure for the cost.

In Europe this method of estimating cost is not uncommon, particularly among architects, though rarely published in that way. It would be well if our cities would gather information regarding time and quantities in their work items and embody it in their annual reports. With it the present difficulties of estimating for new municipal work would be largely removed.

If work data were recorded more frequently than heretofore, and

depended on fixed bases, such as per individual, hour, weight, or measure, the information would be more intelligible, accurate, and useful than at present. Whenever such information was available for the subjects discussed in this book, it has been given.

We believe that it will be seen in the following chapters that the whole subject of refuse collection and disposal, both theoretically and practically, has almost entirely passed the period of speculation and experiment. With much better prospects of success, now than formerly, and with but few elements lacking, it is possible to forecast, both in efficiency and cost, the results of the best known methods and works.

Therefore, after the best solution for the local requirements has been ascertained and the most suitable works have been built, their final success depends almost wholly on the competence of those charged with their operation.

CHAPTER I

REFUSE MATERIALS

Municipal refuse materials are the solid waste matters resulting from the natural activities of a community. Their proper collection and final disposal depend on the character of the particular materials to be dealt with. They are distinct from the liquid portions of community wastes—generally called sewage—yet some of them, although substantially solid in structure, contain large quantities of moisture.

A.—DEFINITIONS

The general term "refuse" includes the following classes of waste material:

1. Street Refuse.—The rejected material collected from public streets and alleys; it includes snow, street sweepings, leaves, cleanings from public catch-basins, and waste building materials. (See Chapter XV.) It also includes those large dead animals which require removal by the community. (See Chapter XVI.)

2. Trade Refuse.—The solid waste from factories, slaughter houses, and business establishments; it includes steam ashes and trade rubbish.

3. Market Refuse.—A special trade refuse, made up chiefly of garbage and rubbish, and coming—either separately or combined—from commission houses and public markets.

4. Stable Refuse.—Substantially manure and straw. (See Chapter XIV.)

5. House Refuse.—Chiefly garbage, ashes, rubbish, and night-soil, from houses, apartments, small stores, schools, churches, hotels, and other establishments which do not themselves dispose of the solid refuse they produce.

6. Garbage.—Garbage is the animal and vegetable waste matter originating in houses, kitchens, restaurants, and hotels, and includes the natural content of moisture and generally, also, the tin cans in which portions of the food were originally supplied. It is chiefly food

waste, and consists almost entirely of organic matter and water. Much of it, particularly the animal matter, readily breaks down, and, in warm weather, soon becomes foul. The oxygen of the air is not absorbed fast enough to prevent the beginning of putrefaction in warm moist weather within 24 hours, and consequently offensive odors may arise.

Garbage is an important part of the refuse, and may have a fair commercial value, because it contains animal and plant foods, and more or less grease; it is important also because, if not properly and quickly disposed of, it is likely to create a serious nuisance. It has been the subject of more discussion, the treatment has been more varied, and there is still more difference of opinion regarding the proper method of disposing of it, than in the case of any other kind of refuse.

With reference to the fermentation of garbage, Mr. Edward D. Very * may be quoted, as follows:

> "Fresh garbage, as it reaches the can, will remain, in ordinary weather, at a temperature of about 70° F., for from 12 to 14 hrs. before any change takes place. From that time alcoholic fermentation sets in, and this will continue for another period of, approximately, 12 to 14 hrs. If the can is loosely covered, acetic acid fermentation develops, but if cans are fairly well closed, the alcoholic fermentation continues for about 36 hrs., after which there is practically no further action. * * * By test it has been found that in garbage which has remained in the can under ordinary temperatures for from 3 to 4 days, and even as long as 21 days, the free fatty acids of the grease are not more than from 5 to 7%, whereas where matter of a like nature is subjected to putrefactive action, the grease analyzes from 30 to 40% of free fatty acids, which indicates the absence of decomposition in ordinary garbage as it is contained in the can.
>
> "The fermentation noted develops small amounts of alcohol and acetic acid, with slight changes in the vegetable oils, but none in the animal oils.
>
> "The sour odor of garbage is the result of this fermentation developing acetic acid, together with certain fruit esters,† aldehydes, and alcohol."

The terms "slops," "offal," or "swill," are sometimes applied to garbage, but they will not be used in this sense in the present volume. In some special instances, the term "garbage" is used as excluding tin cans, particularly where it is delivered for final disposal either at reduction works or at hog farms. It has also been used to indicate a mixture of garbage with rubbish, or even with ashes. We do not give it these meanings.

7. Ashes.—House ashes are defined as the residue from coal and

* In a paper before the Society of Chemical Industry, March 20th, 1908.

† An ethereal salt consisting of an organic radical and any oxygen acid.

wood fires in dwelling houses, schools, churches, stores, and small business establishments, but may include also small quantities of other inorganic materials, as glass, crockery, metallic substances, bricks, earth, and dust. Steam ashes are defined as ashes from fires under large boilers, and are then generally considered as a part of trade refuse. They do not differ materially from house ashes, except that they contain less foreign material; in Milwaukee they were found to have about the same useful calorific value. Usually, they do not contain as much cinder or unburned coal, nor as much dust, as house ashes.

8. Rubbish.—Rubbish comprises miscellaneous materials from houses and stores, such as are not classed specifically under garbage or ashes. It consists chiefly of wood, paper, rags, bedding, excelsior, straw, leather, rubber, old furniture, stoneware, glass, boxes, barrels, etc., and sweepings from buildings. The most objectionable parts of refuse of this class are the dust and possibly pathogenic germs which may be contained in cast-off clothing, bedding, and sweepings. Under ordinary conditions, its odor is but slightly offensive, and its decomposition is slow and not putrescent.

9. Mixed Refuse.—In many communities, especially in Europe, garbage, ashes, and rubbish are placed together in one receptacle at the house; thereafter they do not exist as separate and distinct classes of city waste. A mixture of garbage, ashes, and rubbish, resulting from their combined treatment at the house and in their collection, as distinct from a separate collection, will be called mixed refuse.

Mixed refuse, from the point of view of cleanliness, presents several advantages. The greatest nuisances from garbage, when it is kept separate, are caused by the odors from putrefaction and from the foul free liquids. Both nuisances are moderated and sometimes even prevented for several days if the garbage is mixed with ashes and rubbish. The greatest nuisance from ashes alone is the dust which is blown from them. Moist garbage, when mixed with ashes, tends to lessen the quantity of this dust. The greatest nuisance from rubbish is caused by the loose paper which is blown away from the can, wagon, or dump, and this is less likely to happen if the rubbish is weighted down with garbage and ashes. The mixed refuse, further, has a greater fuel value than any one of its separate materials. On the other hand, if ashes and rubbish are mixed with garbage, the recovery of grease from the latter is made impracticable, and also the utilization of the food values.

10. Night-Soil.—This term is applied to the contents of privies and cesspools used at houses for which there are no sewers. (See Chapter XVI.)

B.—CLASSIFICATION

The constituents of refuse are classified in Table 1. This classification, with some modifications, was taken from a paper entitled "Disposal of Municipal Refuse, and Rubbish Incineration," by Mr. H. de B. Parsons.*

The principal subjects which are important in a study of refuse materials are:

(*a*) The quantities produced;
(*b*) Their composition;
(*c*) The relative proportion of the combined materials.

The quantities of refuse, their composition, and the various proportions in which they occur when collected together, can be ascertained with a fair degree of accuracy from the published records and reports of city officials having charge of refuse disposal work. However, this source of information is neither uniform, nor always accurate, which detracts somewhat from its practical usefulness unless detailed conditions governing the record are also given. (See Chapter I, D.) In some instances, only the number of loads of refuse collected is recorded, and the tonnage estimated from this record is based on an assumed weight per load, or at best on a few scattered weighings. The following statement by the Secretary of the Health Department of Milwaukee, Mr. A. B. Cargill, in his annual report for 1910, shows how errors may result.

"It will be noted under the reports of garbage collection that there is a decrease in the tonnage although an increase is shown in the number of loads. This is due almost entirely to the fact that a new method for weighing garbage has been employed since the installation of the new plant. During the preceding four years, estimates were made of the tonnage, based upon the actual weights of three sample loads per day. This was the best method available under the circumstances, as we had no facilities for weighing all of the garbage received. In fact, it was a much more accurate plan than that employed in most cities. With the erection of the new refuse incineration plant, however, a wagon scale was built, and since that time we have been weighing every load of garbage and other refuse received. The results clearly indicate that in the past our method of weighing has been (as we knew it was) faulty. It has shown, however, that the Department has been over-weighing. This has been unavoidable and unintentional. It is a matter of satisfaction that the city is now receiving its tonnage and figuring its cost per ton upon absolutely reliable figures and not upon estimates, as has been true in the past.

"In making a comparison of the costs per ton with previous years, therefore, the facts stated above must be taken into consideration, and the per-

* *Transactions*, Am. Soc. C. E., Vol. LVII (1906), p. 45.

TABLE 1.—CLASSIFICATION OF REFUSE MATERIALS

Municipal Refuse	Public Refuse		Street Manure and Litter
			Sweepings and Dust
			Leaves
			Droppings from Carts
			Large Dead Animals
			Snow
			Cleanings from Public Catch-basins
	Trade Refuse		Steam Ashes
			Dry Factory Wastes
			Slaughter House Waste
			Rubbish from Office Buildings and Factories
			Cleanings from Private Catch-basins
	Market Refuse		Garbage from Markets
			Rubbish and Cleanings from Markets
			Old Boxes and Barrels
	Stable Refuse		Manure
			Straw
			Cleanings from Stables
			Fly Maggots
	House Refuse	Garbage	Animal Matter, including moisture
			Vegetable Matter, including moisture
			Tin Cans
			Small Dead Animals
		Ashes	Coal and Cinders
			Clinker and Slate
			Dust
			Glass
			Crockery
			Brick and Stone
			Metal Fragments
		Rubbish	Sweepings from Buildings
			Boxes and Barrels
			Wood
			Paper
			Rags
			Excelsior
			Straw
			Leather
			Rubber
			Metal Ware
			Bedding
			Old Furniture
		Night-soil	Contents of Privies

centage of over-weighing in past years must be figured in, if such comparisons are to be accurate and fair."

Exceptions to the many former inaccurate statements are the contents of a number of annual reports of recent date.

C.—SPECIAL INVESTIGATIONS

The most helpful sources of information on the subject of refuse materials are the special investigations and reports which have been made under various authorities.

The first comprehensive investigation of the subject of refuse disposal in America was begun in 1887 by the Garbage Committee of the American Public Health Association, of which Mr. Rudolph Hering later was Chairman. This Committee published several reports in the *Transactions* of the American Public Health Association, the Final Report appearing in 1897. As a result of these general investigations, several large cities undertook special examinations of their refuse disposal problems. The earliest of these was in Brooklyn, in 1896, by Messrs. Taylor and Locke. At about the same time Mr. R. H. Thomson made a report on the refuse disposal problem for Seattle. Following these, investigations were made in New York City, by Col. George E. Waring, Jr., in 1898, and in Trenton, N. J., by Mr. Rudolph Hering, assisted by Mr. Theodore Horton, in 1902.

Since 1902 there has been a marked increase in the number of such investigations, although many of these studies do not include detailed analyses, measurements, and weights of refuse materials. A few are described below.

1. Buffalo, N. Y.—In 1902 Mr. Olin H. Landreth was commissioned by the City of Buffalo to make an investigation for improved methods of refuse disposal. The results are published in the *Papers and Reports* of the American Public Health Association, Vol. 28, 1902.

2. Boston, Mass.—Between 1905 and 1910 investigations and reports were made on the refuse disposal of Boston. The author of the first report was Mr. X. H. Goodnough, Chief Engineer of the Massachusetts State Board of Health.* This general report was followed by special reports, to the Mayor of Boston, containing much valuable information relative to daily quantities of refuse. The data are arranged to show the variation in the quantities produced during different seasons and in different districts of the city. It is one of the earliest American reports in which comprehensive and careful statistics of refuse materials and their disposal are presented.

* *Journal*, Assoc. Eng. Soc., May, 1908.

3. New York, N. Y.—In 1907 Messrs. Parsons, Hering, and Whinery presented to the Mayor of New York a comprehensive report on street cleaning and refuse disposal. Some data from this report relative to the quantities of refuse materials collected from the Boroughs of Manhattan, Brooklyn, and The Bronx for 1905 are shown in Table 2, together with later data for 1910 to 1917, inclusive.

The unit weights, per cubic foot, of garbage, ashes, and rubbish are given in Table 3, and also later data from other cities. These data were secured from actual measurements of a large number of wagons at the various city dumps. The foregoing report also contains valuable information relative to the chemical composition of house refuse. This is shown in Tables 4 and 5.

Table 2.—Quantities of Refuse Materials Collected in the Boroughs of Manhattan, Brooklyn, and The Bronx, of New York City, in 1905, and from 1910 to 1917, inclusive

(From Reports of Department of Street Cleaning)

Year	Population	Pounds per Capita per Annum				Cubic Feet per Day per 1000 Population			
		Garbage	Ashes	Rubbish	Totals	Garbage	Ashes	Rubbish	Totals
1905*	3,833,618	187	955	92	1234	12.55	66.42	46.32	125.29
1910	4,396,873	157	1401	89	1647	11.64	86.36	46.15	144.15
1911	4,575,000	141	1443	88	1672	10.42	88.93	45.76	145.11
1912	4,743,771	148	1430	95	1673	10.94	88.16	49.16	148.26
1913	4,917,220	158	1360	103	1621	11.70	83.87	53.12	148.69
1914	5,190,779	159	1302	94	1555	11.75	80.26	48.68	140.69
1915	5,018,870	175	1305	113	1593	12.94	80.41	58.25	151.60
1916	5,138,532	166	1345	105	1616	12.26	82.93	54.28	149.47
1917†	5,241,302	153	1345	91	1589	11.30	82.91	46.96	141.17

* From Report of Parsons, Hering, and Whinery, 1907.

† The quantities for 1917 are based on records for 11 months, Jan. 1 to Nov. 30.

4. Rochester, N. Y.—In 1906 Mr. Edwin A. Fisher, City Engineer of Rochester, published a report on the collection and disposal of garbage and other city refuse. This report contains a digest of several special and annual reports, together with cost data for the collection and disposal of refuse materials.

5. Milwaukee, Wis.—In the latter part of 1907, Hering made a comprehensive report on garbage disposal for the City of Milwaukee, to Dr. G. A. Bading, Health officer, recommending the building of a high-temperature incinerator to burn the mixed refuse of the city.

This report gives statistics as to the quantities of refuse materials and the costs for collection and disposal. A recent record of monthly variations in the quantities of different kinds of household refuse for Milwaukee, Wis., is given in Table 14 under Seasonal Variations.

6. West New Brighton, N. Y.—On December 18th, 1907, Mr. J. T. Fetherston presented to the American Society of Civil Engineers a comprehensive paper * describing investigations for refuse disposal in

TABLE 3.—UNIT WEIGHTS OF GARBAGE, ASHES, AND RUBBISH IN SEVERAL CITIES

City	Year	Weight, in Pounds per Cubic Foot			Reference
		Garbage	Ashes	Rubbish	
New York, N. Y.:					
Manhattan and Bronx	1907	41.1	40.0	5.3	Parsons, Hering and Whinery
Brooklyn	1907	41.1	36.1	4.7	Parsons, Hering and Whinery
Richmond	1907	34.5	44.5	7.4	Parsons, Hering and Whinery
Chicago, Ill.	1912	39.4	......	....	Osborn-Fetherston
Boston, Mass.	1906–07	42.5	50.0	7.8	Goodnough, *Jour. Assoc. Eng. Soc.*, May, 1908
Buffalo, N.Y.	1913	....	......	5.0	Norton
Columbus, Ohio	1909–10	43.7	......	....	State Bd. of Health Rept., 1910
Cleveland, Ohio	1909–10	50.2	......	....	State Bd. of Health Rept., 1910
Dayton, Ohio	1909	54.5	......	....	State Bd. of Health Rept., 1910
Cincinnati, Ohio	1909–10	45.4	......	....	State Bd. of Health Rept., 1910
Milwaukee, Wis.	1912	36.1	......	....	Winter
	1912	28.7	......	....	Summer
Rochester, N. Y.	1906	43.3	......	7.4	Fisher, E. A.
San Francisco, Cal.	1908–09	41.0	41.0	22.0	Dept. Public Works, June, 1910
Trenton, N. J.	1913	44.5	43.3 (wet)	....	Hering and Gregory
	1913	....	36.4 (dry)	....	Hering and Gregory
Washington, D. C.	1915	....	......	7.5	Osborn
	1915	....	40.8	....	
Los Angeles, Cal.	1915–16	44.5	.. ....	13.7	Knowlton, W. T.

the Borough of Richmond, New York City. This paper gives records of the quantities, proportions, and composition of the refuse materials collected during a period of several years. In Table 6 are data taken from this report to show the quantity of house refuse, by volume and weight, collected in the West New Brighton District of the Borough of Richmond, and to show the composition of house refuse by months throughout the year.

* *Transactions*, Am. Soc. C. E., Vol. LX (1908), p. 345.

7. San Francisco, Cal.—For several years prior to 1910 the Department of Public Works of San Francisco made investigations into the quantities and characteristics of the refuse materials produced in that city. The resulting statistics are tabulated and published in "Specification No. 5452, Garbage Disposal System," dated June, 1910, from which Table 7 is taken.

TABLE 4.—ANALYSES OF GARBAGE IN NEW YORK CITY

(Data from Parsons, Hering, Whinery Report, 1907)

Sample	A	B	C	D	E
Place where sample was taken	....	E. 107th Street dump	Stanton Street dump	W. 47th Street dump	Far Rockaway dump
Moisture	65.90	76.00	60.00	65.00	73.00
Volatile combustible matter	34.10 (Volatile combustible matter, fixed carbon, and inorganic matter together)	17.80	29.74	25.85	17.36
Fixed carbon		2.85	4.82	4.47	2.78
Inorganic matter or ash		3.35	5.44	4.68	6.86
	100.00	100.00	100.00	100.00	100.00
Included in above:					
Grease	7.07	3.52	7.22	6.82	2.83
Phosphorus pentoxide	0.07	0.26	0.93	0.58	0.57
Potassium oxide	0.30	0.31	0.33	0.35	0.49
Nitrogen	0.86	0.73	1.25	0.83	0.95
Calorific value of dry material, in B.t.u.	.....	8803	9335	8831	8774
Calorific value calculated to original material containing original percentage of moisture, in B.t.u.	.....	1114	2945	2236	1409

8. Ohio Cities.—The State Board of Health of Ohio, Mr. R. W. Pratt, Chief Engineer, published a report in 1910 giving information as to refuse materials in many Ohio cities and towns. Four cities in particular were closely studied, and the information given in detail. Some of the data in this report, however, rest on assumed bases, where records of unit quantities were not available. Figs. 1, 2, and 3, and some data in Tables 8 and 9 are taken from this report.

9. Chicago, Ill.—Early in 1914, Messrs. I. S. Osborn and J. T. Fetherston made a report on the collection and disposal of garbage and refuse in Chicago, Mr. Samuel A. Greeley being in charge of the field investigations.

TABLE 5.—ANALYSES OF ASHES IN NEW YORK CITY

(Data from Parsons, Hering, Whinery Report, 1907

	Percentage by Weight										
	Ashes from city dumps					Household ashes					
Sample	A	B	C	D	E	F	G	H	J	K	L
						Private Residences, Manhattan					
Place where sample was taken	Clinton St. dump, Manhattan	Stanton St. dump, Manhattan	W. 47th St. dump, Manhattan	W. 47th St. dump, Manhattan	E. 107th St. dump, Manhattan	Ash from grate burning cannel coal	Ash from stove burning anthracite stove No. 2	Ash from hot-air furnace burning anthracite, egg size	Ash from private residence, E. 38th St.	From apartment house	From hotel.
Moisture	1.69	0.80	0.83	0.93	1.20	0.64	0.36	0.06	1.44	0.81	0.62
Volatile combustible matter	36.12	31.77	35.44	21.71	13.39	21.83	8.83	13.44	15.03	3.04	0.87
Fixed carbon				22.17	20.87				17.37	27.71	31.96
True ash	62.19	67.43	63.73	55.19	64.54	77.53	90.81	86.50	66.16	68.44	66.55
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Analyses calculated to original material:											
Water	.....	.....	.....	42.00	22.85	.....	.....	.....	30.00	27.51	11.62
Volatile combustible matter	.....	.....	.....	12.71	10.45	.....	.....	.....	10.67	2.22	0.78
Fixed carbon	.....	.....	.....	12.98	16.30	.....	.....	.....	12.34	20.25	28.42
True ash	.....	.....	.....	32.31	50.40	.....	.....	.....	46.99	50.02	59.18
Totals	.....	.....	.....	100.00	100.00	.....	.....	.....	100.00	100.00	100.00

TABLE 6.—HOUSEHOLD REFUSE AS COLLECTED, WEST NEW BRIGHTON DISTRICT

The data in this table are taken from a paper by J. T. Fetherston, in *Transactions*, Am. Soc. C. E., Vol. LX (1908), p. 345

Month	Garbage						Ashes and Rubbish						Total Collection			
	Volume			Weight			Volume			Weight			Volume		Weight	
	Cubic yards	Percentage of 12 months' collection	Percentage of total monthly collection	Tons	Percentage of 12 months' collection	Percentage of total monthly collection	Cubic yards	Percentage of 12 months' collection	Percentage of total monthly collection	Tons	Percentage of 12 months' collection	Percentage of total monthly collection	Cubic yards	Percentage of 12 months' collection	Tons	Percentage of 12 months' collection
1906																
January	409	5.7	16.9	190.6	5.7	16.5	2,014	9.3	83.1	962.9	10.6	83.5	2,423	8.4	1,153.5	9.3
February	265	3.7	12.5	123.5	3.7	12.4	1,852	8.6	87.5	871.5	9.6	87.6	2,117	7.4	995.0	8.0
March	373	5.2	14.5	173.8	5.2	14.0	2,199	10.2	85.6	1072.7	11.8	86.0	2,572	9.0	1,246.5	10.1
April	545	7.7	21.7	254.0	7.7	20.7	1,972	9.1	78.3	973.8	10.7	79.3	2,517	8.8	1,227.8	9.9
May	574	8.1	23.6	267.5	8.1	21.3	1,857	8.6	76.4	890.4	10.9	78.7	2,431	8.5	1,257.9	10.2
June	617	8.7	26.3	287.5	8.7	28.1	1,725	8.0	73.7	734.0	8.1	71.9	2,342	8.2	1,021.5	8.2
July	653	9.2	30.1	304.3	9.2	41.7	1,516	7.0	69.9	426.0	4.7	58.3	2,169	7.5	730.3	5.9
August	753	10.6	31.2	350.9	10.6	45.7	1,661	7.7	68.8	417.4	4.6	54.3	2,414	8.4	768.3	6.2
September	889	12.5	34.7	414.3	12.5	49.1	1,677	7.7	65.3	429.1	4.7	50.9	2,566	8.9	843.4	6.8
1905																
October	803	11.3	33.9	374.2	11.3	39.9	1,567	7.2	66.1	564.7	6.2	60.1	2,370	8.2	938.9	7.6
November	652	9.2	28.0	303.8	9.2	28.6	1,678	7.8	72.0	759.8	8.4	71.4	2,330	8.1	1,063.6	8.6
December	574	8.1	23.3	267.5	8.1	23.4	1,894	8.8	76.7	877.5	9.7	76.6	2,468	8.6	1,145.0	9.2
Totals	7107	100		3311.9	100		21,612	100		9079.8	100		28,719	100	12,391.7	100
Percentages of total collection	24.8			26.7			75.2			73.3			100		100	
Average quantities per 1000 inhabitants per day	0.91 cu. yd.			0.425 ton			2.77 cu. yd.			1.164 tons			3.68 cu. yd.		1.589 tons	

Daily collection of refuse, except Sundays and holidays. Average weights per cubic yard: Ashes and rubbish =0.42 ton; garbage =0.466 ton; One ton =2,000 lb.

In December, 1913, and in January and February, 1914, nineteen loads of mixed ashes and rubbish were weighed and then separated by hand into the items listed in Table 10. Summer conditions for Chicago are shown in Table 11.

TABLE 7.—COMPUTED FROM DATA OBTAINED FROM ANALYSES OF SAMPLES COLLECTED FROM THE ENTIRE CITY OF SAN FRANCISCO ON THE DATES INDICATED.

(From "Specification No. 5452, Garbage Disposal System")

Date	Unit weight of refuse in pounds per cubic foot	Percentage of combustible in refuse, by weight	Percentage of incombustible in refuse, by weight	Percentage of moisture in refuse, by weight	Heating Value of the combustible in refuse, in B.t.u. per pound	Heating Value of refuse as collected, in B.t.u. per pound
Dec. 7, 1908....	31.1	22.65	26.45	50.90	10,836	2,457
Dec. 10, 1908....	29.5	22.46	25.37	52.17	10,540	2,352
Dec. 17, 1908....	27.0	23.34	29.53	47.13	10,588	2,481
Dec. 29, 1908....	29.6	23.06	27.71	49.27	10,330	2,388
Jan. 28, 1909....	32.2	23.16	28.37	48.47	10,230	2,366
Averages.....	29.7	22.9	27.2	49.9	10,530	2,410

Note.—The percentages of combustible, incombustible, and moisture, and the heating values stated in this table were obtained by experiments outlined as follows: Small samples were taken at random from each load as it was dumped into the receiving bins, and all the samples collected from the loads from each section during the day were thrown into a pile. This pile was then thoroughly mixed and divided until a sample of about 1 cu. ft. was obtained. It was chopped up, mixed, and divided until a sample of 1 qt. was obtained. This was dried in a small oven until no further reduction of weight was observed, thus determining the moisture. The combustible was then determined from these samples in a chemical laboratory, the heating value being ascertained with a bomb calorimeter.

10. Washington, D. C.—During 1915, Mr. I. S. Osborn made a careful investigation of refuse disposal for Washington, D. C. In co-operation with the Bureau of Soils, many analyses were made of different kinds of refuse. Some of the data appear at the close of this chapter. The report * recommended the reduction of garbage, the burning of rubbish, and the dumping of ashes.

11. Danville, Ill.—In 1916, Greeley made investigations in two smaller cities, Danville (population 35,000) and Galesburg (population 25,000) in Illinois. Data on refuse collection conditions are pre-

* House Document No. 661, 1916.

sented together with recommendations for ordinances, house treatment, collection work, burial of garbage, sorting, burning of rubbish,

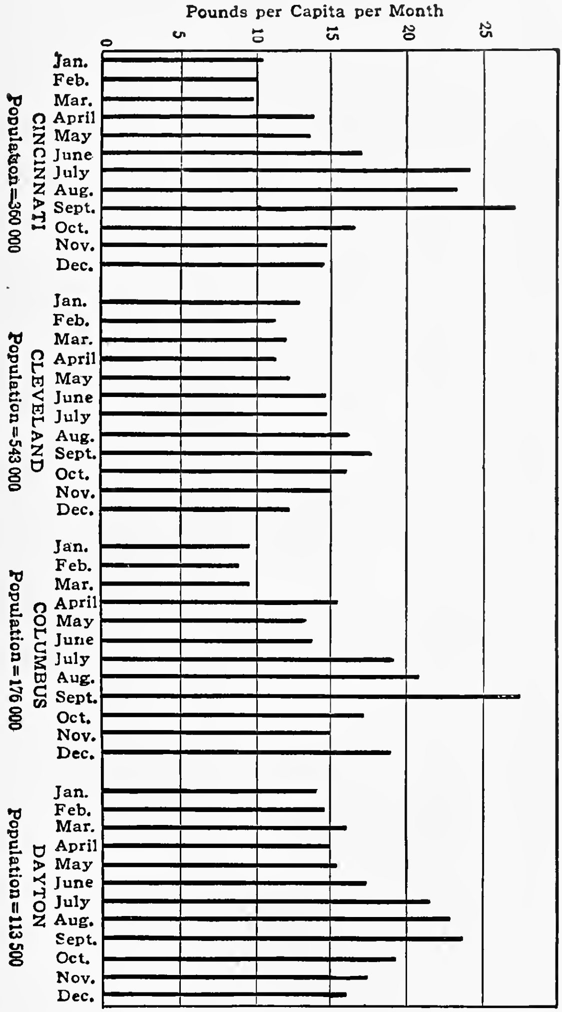

Fig. 1.—Quantities of Garbage Collected in 1909, in Ohio Cities, in Pounds per Capita per Month.

and dumping of ashes. The report also contains data on seasonal variations in the quantities of refuse materials.

12. Louisville, Ky.—During the summer of 1917, the refuse disposal problem of Louisville was studied thoroughly by Greeley, assisted by Professor Frederic Bonnet, Jr., of Worcester, Mass. This work was carried out by the aid of a fund raised by the Women's City Club, and, with its active assistance, many useful data were obtained at a minimum of cost. Tabulated statistics of the house treatment and collection service are given in Table 49.

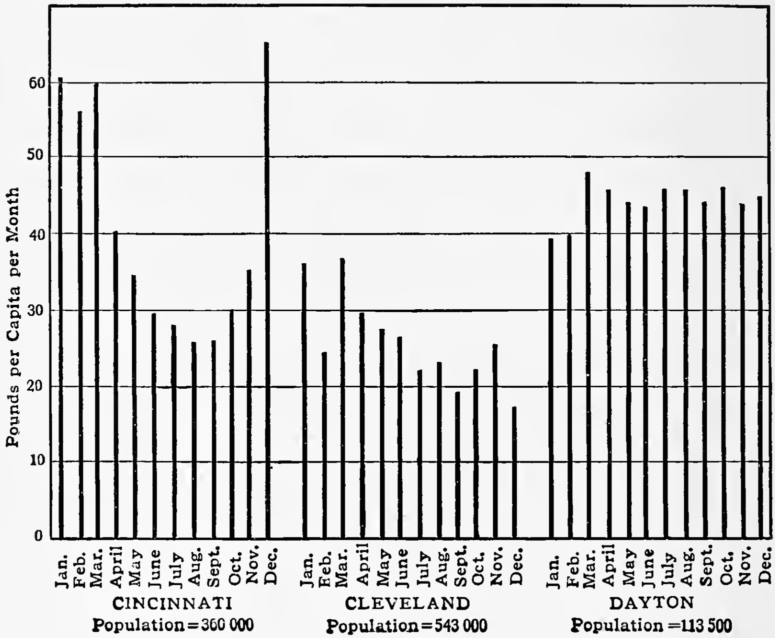

Fig. 2.—Quantities of Ashes and Rubbish Collected in 1909, in Ohio Cities, in Pounds per Capita per Month.

Professor J. H. James, in 1908, made an analysis of the Louisville refuse, and also determined its calorific value. The data are set forth in Table 12.

13. Other Investigations.—There are numerous other investigations and compilations from which we have taken data and statistics, as, for instance, from the United States Census for 1905, and the reports made for the Cities of Columbus, Ohio, Toronto, Ont., and Newark, N. J. Municipal authorities have recently conducted investigations at Cincinnati, Ohio, Springfield and Worcester, Mass., Dallas, Tex., Baltimore, Md., San Francisco, Cal., New Orleans, La., and elsewhere, and all have added to the available information.

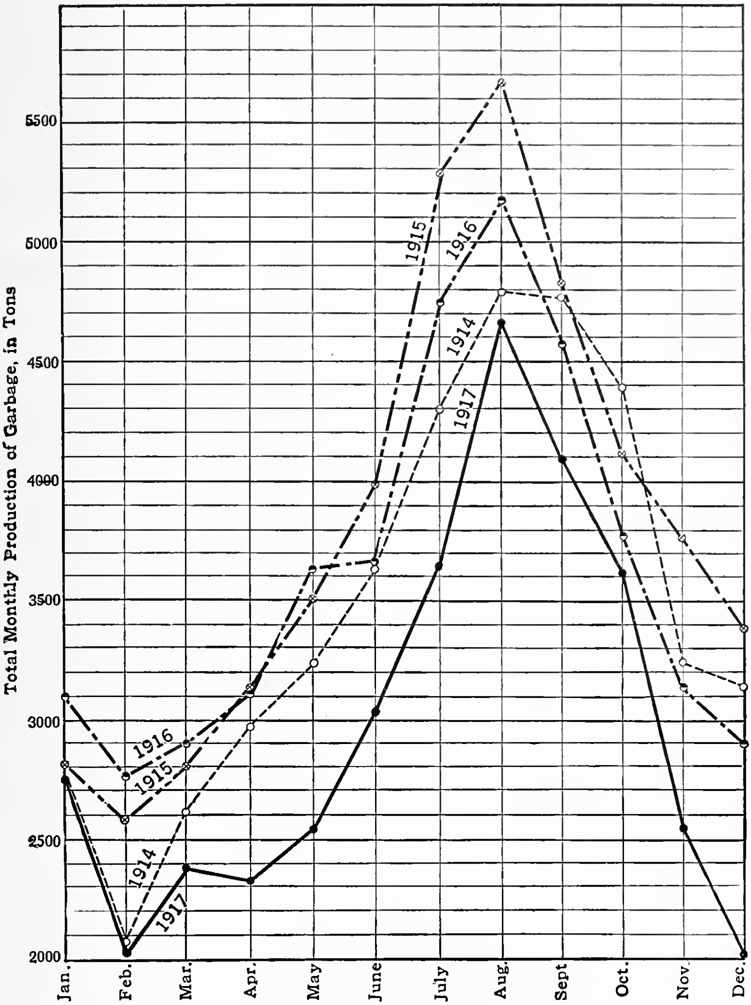

FIG. 3.—Comparison of Monthly Variation in the Production of Garbage in Cincinnati, Ohio, for 1914, 1915, 1916, and 1917.

TABLE 8.—CHEMICAL ANALYSES OF GARBAGE, WITH SPECIAL REFERENCE TO THE REDUCTION PROCESS

City	Percentage by Weight				Reference
	Grease	Phosphoric acid	Nitrogen	Potash	
New York City:					
Sample A........	7.07	0.07	0.30	0.86	Parsons, Hering, Whinery
Sample B........	3.52	0.26	0.31	0.73	
Sample C........	7.22	0.93	0.33	1.25	
Sample D.......	6.82	0.58	0.35	0.83	
Sample E........	2.83	0.57	0.49	0.95	
Milwaukee, Wis...	1.93	0.51	0.35	....	Professor Sommer
Cincinnati, Ohio...	4.02	0.29	0.64	0.28	State Board of Health
Cleveland, Ohio...	3.85	0.24	0.64	0.30	
Columbus, Ohio...	3.96	0.22	0.59	0.25	
Dayton, Ohio.....	3.83	0.19	0.51	0.20	
Washington, D. C..	5.12	0.39	0.71	0.28	Average of 69 analyses
Los Angeles, Cal...	1.71	1.96	3.05	1.22	*Eng. News*, Vol. 76, p. 679
Chicago, Ill.......	2.04	3.81	2.65	0.85	*

* For Chicago the following information has been reported by Harry F. Towle, General Foreman in Charge, Bureau of Waste Disposal, Dept. of Public Works, under date of November 22, 1919:

"Average analysis of finished tankage shipped during October, 1919:

"Moisture	5.40%
Ammonia	2.78%
Bone phosphate of lime	4.23%
Potash	0.94%

"The garbage grease produced at this plant at the present time is running from 6 to 8% in total impurities and from 15 to 20% in free fatty acids. The analysis on the last car shipped was:

"Total impurities	6.73%
Free fatty acids (as oleic)	15.02%
Volatile at 105° C	0.70%
Unsaponifiable matter	5.85%
Petroleum ether insoluble	0.03%
Soluble mineral matter	0.15%
Saponification number of grease	186.4
Glycerine (combined)	8.63%"

TABLE 9.—PROXIMATE ANALYSES AND CALORIFIC VALUES OF REFUSE

City	Year	Material	Percentage by Weight			British Thermal Units per Pound		Reference	
			Moisture	Combustible *	Incombustible	Combustible in refuse	Refuse as collected		
New York....	1905	Garbage	71.4	23.4	5.2	10,233	2398	Average of 7 samples	*Trans.* Am. Soc. C. E., Fetherston, 1908
New York....	1905	Coal and cinders	1.64	44.29	54.06	11,066	4901	Average of 7 samples	*Trans.* Am. Soc. C. E., Fetherston, 1908
New York....	1905	Rubbish	1.83	85.32	12.85	9,889	8437	Average of 7 samples	*Trans.* Am. Soc. C. E., Fetherston, 1908
Cincinnati....	1909–10	Garbage	76.6	19.7	3.7	10,152	2000	Average of 10 samples	Ohio State Board of Health, 1910
Cleveland.....	1909–10	Garbage	75.6	21.2	3.2	9,703	2057	Average of 28 samples	Ohio State Board of Health, 1910
Columbus.....	1909–10	Garbage	76.4	20.3	3.3	9,823	1994	Average of 31 samples	Ohio State Board of Health, 1910
Dayton......	1909–10	Garbage	80.6	16.8	2.6	10,190	1712	Average of 30 samples	Ohio State Board of Health, 1910
Cincinnati....	1909–10	Ashes	7.8	30.5	61.7	10,121	3087	Average of 7 samples	Ohio State Board of Health, 1910
Cleveland.....	1909–10	Ashes	14.1	22.0	63.9	8,250	1815	Average of 6 samples	Ohio State Board of Health, 1910
Dayton.......	1909–10	Ashes	19.3	21.5	59.2	11,707	2517	Average of 9 samples	Ohio State Board of Health, 1910
Washington...	1916	Garbage,	73.8	22.5	3.6	8,869	2310	Average of 69 samples	Bureau of Soils. U. S. Dept. of Agric.
		Dust	4.5	16.6	78.9	2,875	3074	Average of 45 samples	Bureau of Soils. U. S. Dept. of Agric.
		Cinders	2.1	52.6	45.3	7,858	7932	Average of 45 samples	Bureau of Soils. U. S. Dept. of Agric.
		Rubbish	6.7	79.5	13.8	7,460	....	Average of 26 samples	Bureau of Soils. U. S. Dept. of Agric.
San Francisco.	1908–09	Mixed refuse	49.9	22.9	27.2	10,530	2410	Average of 5 samples	*Eng. Record*, Jan. 15, 1914

* Includes volatile matter

TABLE 10.—PHYSICAL ANALYSES OF WINTER ASHES AND RUBBISH IN CHICAGO, MADE IN DECEMBER, 1913, AND JANUARY AND FEBRUARY, 1914

Number of analyses made	3	10	7
Where made	51st Street and the Lake	Grace and Campbell Ave.	15th Place and Loomis St.
Total weight analyzed, in pounds	18,900	61,395	38,050
Fine ash. Total weight, in pounds	9,322	32,765	18,950
Fine ash. Percentages	46.94 to 52.38	39.42 to 56.09	39.57 to 58.81
Fine ash. Calorific value, in British thermal units	2062 to 6596	1829 to 5340	1742 to 3062
Coal. Total weight, in pounds	7,250	20,123	12,862
Coal. Percentages	30.40 to 46.00	19.57 to 39.84	28.62 to 38.30
Coal Calorific value, in British thermal units	4146 to 8650	1109 to 9605	4612 to 7600
Clinker. Total weight, in pounds	1835	6946	4930
Clinker. Percentages	1.70 to 14.87	5.47 to 21.64	8.29 to 20.74
Bottles, Percentages	0.23 to 2.97	0.09 to 0.74	0.02 to 0.65
Broken glassware, "	0.28 to 0.52	0.00 to 1.43	0.05 to 1.18
Whole glassware, "	....	0.00 to 0.01	....
Broken crockery, "	....	0.00 to 0.51	0.02 to 0.27
Cast iron, "	0.07 to 0.23	0.00 to 0.84	0.00 to 0.14
Brass, "	0.00 to 0.02	0.00 to 0.02	....
Tinware, "	0.07 to 0.97	0.00 to 1.24	0.38 to 1.06
Enamelware, "	0.01 to 0.04	0.00 to 0.06	0.00 to 0.14
Newspapers, "	0.07 to 1.24	0.08 to 0.78	0.00 to 0.61
Manila paper, "	0.00 to 0.44	0.00 to 0.38	0.00 to 0.55
Cardboard, "	0.02 to 0.50	0.00 to 0.99	0.00 to 1.22
Mixed paper, "	0.05 to 0.14	0.05 to 1.52	0.18 to 1.66
Rags, "	0.07 to 0.24	0.00 to 0.82	0.00 to 0.32
Rubber, "	0.01 to 0.02	0.00 to 0.03	0.00 to 0.05
Leather, "	0.01 to 0.14	0.00 to 0.13	0.00 to 0.37
Wood, "	0.04 to 0.08	0.05 to 0.58	0.00 to 0.11
Garbage, "	0.07 to 0.30	0.06 to 4.58	0.14 to 2.00

TABLE 11.—RESULTS OF ANALYSES OF REFUSE IN CHICAGO, FROM JUNE 17, TO SEPTEMBER 16, 1914

(The results are given in pounds)

Groups, as per report	Number of loads	Ashes			Glassware				Metals					
		Fine ash passing $\frac{3}{8}$-in. screen	Ash rejected by screen	Clinker	Number of bottles	Weight of bottles	Broken glass-ware	Broken crockery	Cast iron	Sheet iron	Brass-ware	Wire	Tin-ware	Enamel ware
A	1	1,153	1,278	248	56	43	93	11	5	.....	.....	.....	39	5
B	7	6,390	4,085	607	759	472	308	256	76	188	.....	31	733	102
C	12	12,574	8,798	918	1008	559	591	574	239	311	......	114	1460	160
D	12	12,499	9,402	157	861	540	740	498	123	401	3	220	1903	161
E	14	14,013	6,978	128	761	425	670	523	138	976	.....	171	1237	223
F	7	6,674	4,609	156	441	255	383	253	40	246	.....	70	707	67
Totals	53	53,303	35,150	2214	3886	2294	2785	2115	621	2122	3	606	6079	718
Averages per load	.....	1005.7	663.2	41.77	73.32	43.2	52.92	39.91	11.7	0.40	0.005	11.43	114.7	13.54
Percentages per load	.....	31.41	20.92	1.32	2.31	1.36	1.67	1.29	0.37	1.26	0.0015	0.36	3.62	0.43

Groups, as per report	Number of loads	Miscellaneous Rubbish												Totals
		News-papers	Manila paper	Card-board	Mixed paper	Rags	Rubber	Leather	Wood	Brick	Grass	Yard clean-ings	Gar-bage	
A	1	127	44	107	95	49	.....	65	64	16	.....	.....	308	3,750
B	7	833	300	455	627	199	20	64	331	359	1982	3,664	360	22,442
C	12	1324	484	598	1236	507	.....	165	690	512	2946	2,865	704	38,329
D	12	1031	514	582	1101	490	.....	217	570	566	1163	3,914	835	37,630
E	14	1373	463	641	1742	658	4	323	1048	744	690	8,890	2087	44,145
F	7	714	286	314	820	303	13	123	694	428	843	2,559	1168	21,725
Totals	53	5402	2091	2697	5621	2206	37	957	3397	2625	7624	21,892	5462	168,021
Averages per load	.....	1.02	39.45	49	106.1	41.62	0.07	18	47.1	49.53	14.38	413	103	3170.3
Percentages per load	.....	3.22	1.24	1.55	3.35	1.31	0.0002	0.56	1.49	1.56	0.45	13.03	3.25	.....

In Europe reports on refuse materials and their disposal have been made by Dr. Thiesing at Charlottenburg, Messrs. Bohm and Grohn in Berlin, Dr. Lenormond in Havre, Mr. F. Andreas Meyer in Hamburg, Mr. J. A. Robertson in Greenock, Scotland, and many others.

TABLE 12.—ANALYSES OF REFUSE IN LOUISVILLE, KY.

(From Report by Professor J. H. James)

Sample No.	Composition		Moisture, Percentage	Calorific Value in B.T.U. per Pound	
	Material	Percentage by weight		Wet	Dry at 180° F.
A	Garbage........	73	50.50	3547.2	7166.0
	Rubbish........	11			
	Ashes and dirt...	16			
B	Garbage........	45	42.18	4636.2	8021.0
	Rubbish........	14			
	Ashes and dirt...	41			
C	Garbage........	52	40.7	3445.33	5810.0
	Rubbish........	10			
	Ashes and dirt...	38			
D	Garbage........	46	50.7	3103.2	6294.6
	Rubbish........	17			
	Ashes and dirt...	37			
E	Garbage........	41	50.5	3151.0	6240.6
	Rubbish........	14			
	Ashes and dirt...	45			
F	Garbage........	36	44.00	2858.5	5105.7
	Rubbish........	6			
	Ashes and dirt...	58			

Recently, the reports of the United States Food Administration have given much valuable information, especially relating to the feeding of garbage to hogs.

D.—QUANTITIES AND THEIR VARIATIONS

Refuse materials, when coming chiefly from residences, are produced in varying quantities, the variations being determined by the following factors:

1. Geographical location of municipality;
2. Season of the year;
3. Character of the population; as to whether it is industrial, residential, rural, etc.;
4. Efficiency of the department or agency which collects the refuse materials;
5. Influence of war.

Mr. Edward D. Very* states that the average quantity of New York City garbage produced per capita per day is ½ lb., and that the average weight is 1100 lb. per cu. yd. (41 lb. per cu. ft.). The average sample contains: 16% animal matter, 79% vegetable matter, and 5% rubbish.

It analyzes approximately as follows: 70% moisture, 20% tankage, 3.5% grease, 1.5% bones, and 5% rubbish.

According to Mr. George Watson, the total house refuse in English cities amounts to 400 (long) tons per annum per 1000 of population (900 lb. per annum per head). According to Codrington, 1 cu. yd. of house refuse weighs from 1400 to 1700 lb.

On the continent of Europe, according to Richter, the total quantity of refuse ranges from ½ to 1 liter per day per person, and its specific gravity varies from 0.65 to 0.85. If we assume a mean of 0.75 liter, the production will be about 0.55 kg. (1¼ lb.) per day per person.

Trade refuse varies chiefly with the number and kind of industries and the condition of business. Street refuse varies in quantity with the kind of pavement and with the frequency as well as the thoroughness and method of cleaning. (Chapter XV.) The quantity of stable refuse depends on the number of horses kept in the community. (Chapter XIV.)

1. Geographical Location.—The effect of the geographical location of a community on the quantity of household refuse produced is readily seen by comparing the unit productions of similar cities in different locations. Table 13 shows the quantities of garbage, ashes, and rubbish produced in 34 American cities.

In considering the effect of geographical location on the production of garbage and ashes, it is reasonable to conclude that the per capita quantities of garbage produced in Southern cities are larger than in the cities of the North, because of the larger quantities of

* Paper before Society of Chemical Industry, March 20th, 1908.

TABLE 13.—PRODUCTION OF REFUSE IN SELECTED AMERICAN CITIES

City	Year	Population	Pounds per Capita per Annum				Cubic Feet per Day per 1000 Population			
			Garbage	Ashes	Rubbish	Totals	Garbage	Ashes	Rubbish	Totals
Baltimore, Md.	1917	589,621	211	.....	.....	.....	.....	.....	.....	.....
Boston, Mass.	1914–15	748,041	204	960	29	1193	13.1	88.5	9.6	111.2
" "	1917–18	781,628	155	829	21	1005	11.4	88.5	7.6	107.5
Buffalo, N. Y.	1905	376,914	131	391		522	.....	.....	.....	.....
" "	1910	423,715	140	652	68	860	.....	.....	.....	.....
Cambridge, Mass.	1905	97,434	230	1029		1259	.....	.....	.....	.....
Chicago, Ill.	1912	2,333,687	109	700		809	8.2	56.0		64.2
" "	1917	2,497,722	80	.....	.....	.....	.....	.....	.....	.....
Cincinnati, Ohio	1905	343,337	146	850		996	.....	.....	.....	.....
" "	1909	360,000	193	486		679	13.1	54.0		67.1
" "	1917	410,476	233	.....	.....	.....	.....	.....	.....	.....
Cleveland, Ohio	1909	543,000	165	312		477	10.6	32.6		43.2
" "	1917	674,073	166	.....	.....	.....	.....	.....	.....	.....
Columbus, Ohio	1912	192,700	195	364		559	.....	.....	.....	.....
" "	1915	210,000	212	.....	.....	.....	.....	.....	.....	.....
" "	1918	223,000	139	.....	.....	.....	.....	.....	.....	.....
Dayton, Ohio	1910	116,577	209	602		811	.....	.....	.....	.....
Detroit, Mich.	1916	571,784	168	.....	.....	.....	.....	.....	.....	.....
Evanston, Ill.	1910	24,978	225	647	236	1108	5.0	47.0	103.2	155.2
Kansas City, Mo.	1917	300,215	299	.....	.....	.....	.....	.....	.....	.....
Los Angeles, Cal.	1915–16	554,000	209	.....	46	255	12.9	.....	9.2	22.1
" "	1917–18	622,000	151	.....	25	176	9.3	.....	5.9	15.2
Lowell, Mass.	1905	94,889	91	927		1018	.....	.....	.....	.....
Lynn, Mass.	1905	77,042	223	927		1150	.....	.....	.....	.....
Milwaukee, Wis.	1914	410,000	188	832		1020	21.0	66.0		86.0
" "	1917	436,535	141	.....	.....	.....	.....	.....	.....	.....
" "	1919	457,000	142	35	8	185	.....	.....	.....	.....
Minneapolis, Minn.	1910	301,408	154	109		263	.....	.....	.....	.....
" "	1917	373,458	138	.....	.....	.....	.....	.....	.....	.....
Nashville, Tenn.	1905	84,227	58	832		890	.....	.....	.....	.....
New Bedford, Mass.	1905	74,362	146	431		577	.....	.....	.....	.....
New York, N. Y.	1905	4,000,403	164	1234		1398	.....	.....	.....	.....
" "	1908	4,258,387	185	913	88	1186	14.7	77.1	55.5	147.3
Paterson, N. J.	1905	111,529	106	898		1004	.....	.....	.....	.....
Philadelphia, Pa.	1917	1,709,518	146	.....	.....	.....	.....	.....	.....	.....
Pittsburgh, Pa.	1916	579,090	.....	.....	77	.....	.....	.....	.....	.....
Rochester, N. Y.	1913	235,000	244	1486	74	1804	.....	.....	.....	.....
" "	1917	265,000	240	1520	80	1840	.....	.....	.....	.....
St. Louis, Mo.	1916	757,309	164	.....	.....	.....	.....	.....	.....	.....
" "	1917	760,454	118	.....	.....	.....	.....	.....	.....	.....
St. Paul, Minn.	1917	247,232	118	.....	.....	.....	.....	.....	.....	.....
San Francisco, Cal.	1909	409,500	323	70	309	702	24.6	5.5	47.5	77.6
Springfield, Mass.	1905	73,540	95	832		927	.....	.....	.....	.....
Syracuse, N.Y.	1905	117,129	153	913		1066	.....	.....	.....	.....
Trenton N. J.	1910	96,815	270	743	*	1013	23.5	59.9	.....	.....
" "	1917–18	113,974	265	853	*	1118	.....	.....	.....	.....
Troy, N. Y.	1905	76,271	248	927		1175	.....	.....	.....	.....
Washington, D. C.	1905	302,883	263	482		745	.....	.....	.....	.....
" "	1912	341,539	292	580	54	926	.....	.....	.....	.....
" "	1915	359,000	286	443	81	810	17.6	28.2	30.1	75.9
" "	1919	450,000	236	.....	.....	.....	.....	11.1	12.3	.....
Wilmington, Del.	1903	83,860	190	661		851	.....	.....	.....	.....

* Included in garbage.

fruit and vegetables consumed there; and, on the other hand, as the consumption of coal is small, the production of ashes there is also small.

The data for Columbus and Dayton, Ohio, where natural gas is available for fuel, show an expected falling off in the quantity of ashes. The production of refuse in the cities of Europe is less than in America, as the people are less wasteful. The average per capita production of house refuse in Europe is approximately 380 lb. per year, as compared with 860 lb. in American cities.

TABLE 14.—QUANTITIES OF GARBAGE, ASHES, AND RUBBISH DELIVERED BY CITY AND PRIVATE COLLECTION, AND DISPOSED OF AT THE MILWAUKEE INCINERATOR DURING 1919

Month	Garbage, in tons	Ashes, in tons	Rubbish, in tons	Manure, in tons	Totals, in tons
January......	2,302.12	806.41	202.92	......	3,311.45
February.....	1,658.57	713.29	198.02	......	2,569.88
March........	1,946.53	879.16	214.58	......	3,040.27
April.........	2,102.31	604.96	144.85	......	2,852.12
May.........	2,397.98	581.98	122.37	......	3,120.33
June.........	2,948.92	510.37	167.76	0.52	3,627.57
July.........	3,477.68	478.92	162.74	2.14	4,121.48
August.......	3,709.89	497.92	142.27	......	4,350.08
September....	3,633.37	600.55	148.32	0.50	4,382.74
October......	3,458.24	553.79	119.64	......	4,131.67
November....	2,580.47	678.32	95.10	......	3,353.89
December.....	2,301.35	989.92	67.55	......	3,358.82
Totals....	32,517.43	7,895.59	1,786.12	3.16	42,202.30

All the garbage of Milwaukee is taken to the incinerator, but the ashes and rubbish from only a part of the city near the incinerator.

2. Season.—There is a marked difference in the quantities of refuse produced from one season to another, and sometimes from day to day, depending on the rainfall and the local conditions of house treatment and collection.

Mr. Very* states that the quantity of garbage produced varies by seasons very materially, with the maximum during the summer, when vegetables and fruits constitute the principal diet, and the minimum during the winter. August has usually the highest record, with about 11% of the total, and February, with about 6%, has the lowest. The moisture content is high in summer and low in winter, whereas the

* Paper before Society of Chemical Industry, March 20th, 1908.

TABLE 15.—MONTHLY VARIATION IN QUANTITY OF REFUSE, IN POUNDS PER 1000 POPULATION PER DAY

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Averages
CHICAGO, 2,262,830. JAN., 1911–DEC., 1911													
Garbage	225	221	238	269	318	366	397	464	512	428	335	296	339.1
Ashes and rubbish	2028	1897	1916	1841	1579	1428	1353	1334	1315	1390	1653	2028	1646.8
Totals	2253	2118	2154	2110	1897	1794	1750	1798	1827	1818	1988	2324	1985.9
BOSTON, 595,380. MAY, 1906–APR., 1907													
Garbage	886	858	858	812	812	821	720	840	840	876	821	876	835.0
Ashes	6090	6280	6190	5870	5170	3950	3560	3710	3625	4160	4590	5600	4899.6
Rubbish	138	129	138	138	138	138	120	129	129	138	·138	138	134.2
Totals	7114	7267	7186	6820	6120	4909	4400	4679	4594	5174	5549	6614	5868.8
CLEVELAND, 543,000. JAN., 1909–DEC., 1909													
Garbage	506	477	461	427	460	572	570	636	693	627	582	466	540.0
Ashes and rubbish	1395	1051	1404	1167	1063	1020	878	935	774	902	1020	667	1023.0
Totals	1901	1528	1865	1594	1523	1592	1448	1571	1461	1529	1602	1133	1563.0
MILWAUKEE, 435,000. JAN., 1916–DEC., 1916													
Garbage	411	370	415	407	509	553	568	615	594	507	407	391	480
Ashes and rubbish	2620	4340	2510	2800	2280	1506	604	612	978	1323	2740	2960	2100
Totals	3031	4710	2925	3207	2789	2059	1172	1227	1572	1830	3147	3351	2580
BUFFALO, 423,715. JAN., 1910–DEC., 1910													
Garbage	505	477	421	364	402	444	435	486	544	511	388	463	453.3
Ashes	3120	3018	2875	2292	1918	1532	1338	1305	1272	1541	2095	3060	2113.8
Rubbish	147	132	175	203	265	265	246	265	251	256	208	227	220.0
Totals	3772	3627	3471	2859	2585	2241	2019	2056	2067	2308	2691	3750	2787.1
CINCINNATI, 360,000. JAN., 1909–DEC., 1909													
Garbage	394	418	378	514	507	675	922	900	1024	609	501	558	622
Ashes and rubbish	2332	2311	2317	1530	1281	1130	1051	979	998	1160	1334	2495	1576
Totals	2726	2729	2695	2044	1788	1805	1973	1879	2022	1769	1895	3053	2198

MINNEAPOLIS, 301,408. JAN., 1910–DEC., 1910

Garbage	384	363	417	494	482	594	636	647	587	529	460	495	507.0
Ashes and rubbish	629	638	573	352	208	105	12	35	83	255	640	842	364.0
Totals	1013	1001	989	846	690	699	648	682	670	784	1100	1337	872.0

DAYTON, 116,577. JAN., 1910–DEC., 1910

Garbage	587	499	741	726	776	827	884	979	1094	970	639	632	779.0
Ashes and rubbish	2382	1985	2935	2788	3350	2039	1113	2296	1776	1930	2012	2386	2250.0
Totals	2969	2484	3680	3514	4126	2866	1997	3275	2870	2900	2651	3018	3029.0

TRENTON, 96,815. JAN., 1910–DEC., 1910

Garbage and rubbish	641	537	641	765	765	889	910	1179	1344	1158	868	724	868.4
Ashes	3905	2873	2662	2292	2420	1529	1447	1487	1880	1900	2768	3658	2401.8
Totals	4546	3410	3303	3057	3185	2418	2357	2666	3224	3058	3636	4382	3270.2

WEST NEW BRIGHTON, 25,900. OCT., 1905–SEPT., 1906

Garbage	534	372	492	709	750	813	858	988	1167	988	802	737	767.5
Ashes	2621	2559	2929	2673	2618	1758	805	673	754	1330	2000	2375	1924.6
Rubbish	267	272	274	263	366	461	503	618	585	468	356	292	393.8
Totals	3421	3203	3695	3645	3734	3032	2166	2279	2506	2786	3158	3404	3085.9

The data in this table have been computed from the following sources:

West New Brighton.—Tables 2 and 3 of J. T. Fetherston's paper, *Trans.* Am. Soc C. E., Vol. LX (1908).

Boston.—Table 2 of X. H. Goodnough's paper, *Jour.* Assoc. Eng. Soc., May, 1908. The daily weights per 1000 population are much greater than in other cities, which may be due partly to Mr. Goodnough's assumption of 5½ days per week.

Buffalo.—Hering and Gregory data.
Chicago.—Fetherston-Osborn Report. Ashes and rubbish taken at 850 lb. per cu. yd.
Trenton.—Hering and Gregory data.
Dayton.—Hering and Gregory data.
Minneapolis.—Table on p. 20 of Report of Board of Health, 1910.
Cleveland.—Tables 28 and 37 of State Board of Health Report, 1910.
Cincinnati.—Tables 47 and 50 of State Board of Health Report, 1910.
Milwaukee, 1914.—Tables on p. 134 of 1914 Annual Report, D. P. W., 1 cu. yd. ashes and rubbish = 1000 lb.
Milwaukee, 1916.—Tables on pp. 92–93 of 1916 Annual Report, D. P. W.

grease content and the chemical plant food values are low in summer and high in winter.

The seasonal variations in the production of household refuse are shown in Table 6 for West New Brighton, N. Y., Table 14 for Milwaukee, Wis., Table 42 for Shanghai, China, Table 45 for Charlottenburg, Germany, and Table 46 for Barmen, Germany.

The seasonal effect on the chemical composition of garbage in Washington D. C., is shown in Table 34.

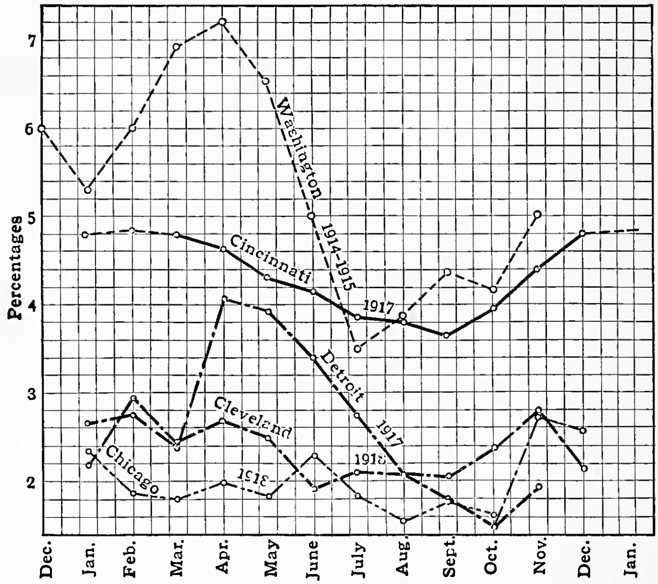

FIG. 4.—Average Monthly Percentages of Grease in Raw Garbage in Several American Cities.

Figs. 3 and 4 and Table 15 present data as to the quantities of garbage, ashes, and rubbish in a number of American cities, in pounds per 1000 population per day.

Table 16 gives the production of refuse for Winnetka and Glencoe, Ill., for summer and winter, and Fig. 5 shows the monthly variations, by weight, in the components of household refuse in the West New Brighton District.

3. Character of Population.—The effect of the character of the population on the quantities of refuse produced is seen by comparing, in the same city, different districts having different general characteristics.

Boston is divided into a number of general sanitary districts. Statistics showing the quantities of garbage, ashes, and rubbish produced in these districts are given in Table 17. For Chicago, where each ward has its own collection service, the quantities of garbage, ashes, and rubbish, in pounds per capita per annum, are given in Table 18. Table 19 has been compiled from the report of the Census Bureau on Statistics of Cities for 1909, the production of refuse being classified as from manufacturing and from residential cities.

TABLE 16.—REFUSE MATERIALS IN WINNETKA AND GLENCOE, ILL.

Quantities in tons per day
Actual quantities for 1912
Estimated quantities for 1920

Year	Total Population, Winnetka and Glencoe	Materials	Summer	Winter	Annual Averages
1912	5853 (Actual)	Garbage......	4.40	2.93	3.50
		Ashes........	2.93	16.12	11.73
		Rubbish......	1.47	1.47	1.47
		Totals.....	8.80	20.52	16.70
1920	9000 (Estimated)	Garbage......	6.84	4.49	5.39
		Ashes........	4.49	24.79	18.01
		Rubbish......	2.25	2.25	2.25
		Totals.....	13.58	31.53	25.65

Notes.—Manure and tin cans are not included.
Garbage as collected, weighs about 1000 lb. per cu. yd.
Ashes, as collected, weigh about 1200 lb. per cu. yd.
Rubbish, as collected, weighs about 150 lb. per cu. yd.

There is a larger production of garbage in residential than in manufacturing cities, and in the wealthier than in the poorer districts of average cities. On the other hand, the unit quantities of ashes produced may be larger in manufacturing cities, although this does not appear in the table, because the quantities given do not include steam ashes produced in the factories.

The effect of different nationalities, in the same community, on the quantity of house refuse produced is shown in Table 20. This has been taken—with some modifications—from a report of the Chicago Bureau of Streets, made by the Efficiency Division of the Chicago Civil Service Commision in 1913. Other cities show similar results.

Washington has long been noted for its high per capita garbage production. This does not indicate extreme wastefulness; the true cause is the complete elimination of the private collectors, and the inclusion of the garbage produced by the city's large floating population, while determining the per capita production on the basis of Washington's permanent population.

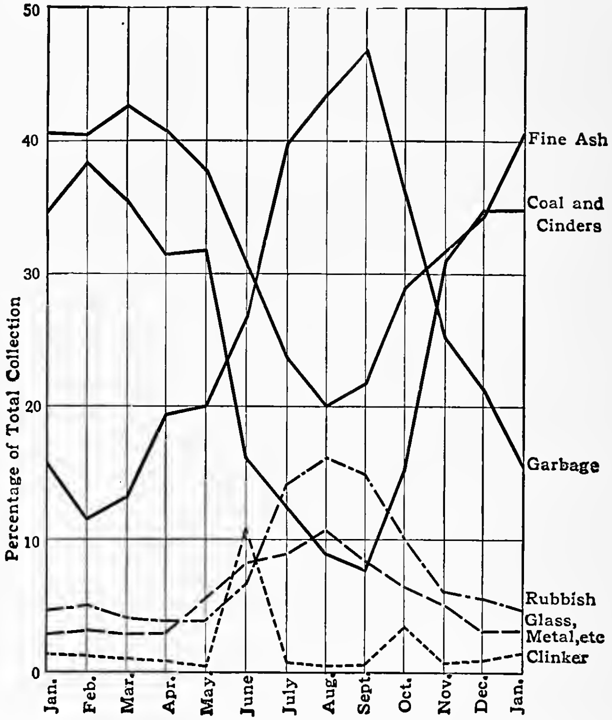

FIG. 5.—Monthly Variations, by Weight, in Components of Household Refuse, West New Brighton District.

4. Departmental Efficiency.—It is important to note that, in all recorded quantities of refuse materials, the energy and thoroughness with which the work of collection is conducted has a marked effect on the record. An energetic and skillful official will increase the unit quantities of refuse collected. The different kinds of pavement, as well as the character, thoroughness, and frequency of cleaning, and, also, the introduction of flushing, have a material influence on the quantity of street refuse.

TABLE 17.—PRODUCTION OF REFUSE IN DIFFERENT DISTRICTS OF BOSTON. IN POUNDS PER 1000 POPULATION. 310 WORKING DAYS

(Data are from Annual Reports)

Year	Materials	District No. 1	2	3	4	5	6	7	8 & 9	10	11
1912–13	Garbage.....	484	334	421	709	795	573	526	1154	543	1606
	Ashes.......	2179	2425	2375	3520	3808	3441	2341	4665	4480	2710
	Rubbish.....	6	....	....	13	2	....	9	378	111	....
	Totals....	2669	2759	2796	4242	4605	4014	2876	6197	5134	3316
1914–15	Garbage.....	386	370	366	964	970	645	582	1025	623	405
	Ashes.......	1835	2420	2210	4450	3750	3160	2235	4275	3925	2100
	Rubbish.....	24	....	....	56	....	74	33	352	103	....
	Totals....	2245	2790	2576	5470	4720	3879	2850	5652	4651	2505
1915–16	Garbage.....	438	348	368	1028	958	641	578	1027	538	521
	Ashes.......	1910	2230	2100	4110	3745	3120	2365	4140	3630	1890
	Rubbish.....	11	....	....	38	25	38	34	327	72	....
	Totals....	2359	2578	2468	5176	4728	3799	2977	5494	4240	2411
1916–17	Garbage.....	404	298	421	963	822	530	504	981	492	574
	Ashes.......	1875	2100	2043	4260	3160	2850	1864	3760	3440	1765
	Rubbish.....	18	....	....	....	34	44	33	370	145	....
	Totals....	2297	2398	2464	5223	4016	3424	2401	5111	4077	2339
1917–18	Garbage.....	385	216	365	572	649	562	435	691	534	388
	Ashes.......	1590	2190	1615	4320	3420	2320	1980	3720	3690	2160
	Rubbish.....	13	....	....	....	40	....	37	250	166	....
	Totals....	1988	2406	1980	4892	4109	2882	2452	4661	3490	2548

The character of the districts is as follows:

1. Mixed business and commercial
2. Mixed business and commercial.
3. All classes.
4. Residential.
5. Residential.
6. Residential.
7. Middle-class residential.

8 and 9. Residential.

10. Mixed.
11. High-class residential.

TABLE 18.—EFFECT OF CHARACTER OF POPULATION ON PRODUCTION OF REFUSE IN THE DIFFERENT WARDS OF CHICAGO, 1912

(Pounds per capita per annum)

Ward	Garbage	Ashes and rubbish	Character of population
1	89	978	Commercial
2	160	905	Commercial and manufacturing
3	148	669	Mixed
4	107	604	Manufacturing
5	75	374	Mixed
6	113	492	Residential
7	110	711	Residential
8	459*		Mixed
9	555*		Mixed
10	77	532	Manufacturing
11	70	578	Manufacturing
12	73	364	Manufacturing
13	158	686	Residential
14	107	604	Mixed
15	138	581	Residential
16	81	485	Manufacturing and commercial
17	101	477	Manufacturing and commercial
18	126	892	Commercial
19	80	698	Commercial
20	111	939	Commercial
21	116	1176	Residential
22	77	649	Residential and commercial
23	148	810	Residential
24	115	633	Mixed
25	146	568	Residential
26	136	670	Mixed, chiefly residential
27	67	270	Undeveloped
28	101	509	Mixed
29	55	340	Undeveloped
30	126	582	Mixed
31	143	530	Mixed
32	114	570	Residential
33	121	422	Residential
34	104	570	Residential and commercial
35	126	477	Mixed

* Garbage, ashes, and rubbish collected together.

A better service secures a more thorough collection. During a 4-year term, as Health Commissioner of Milwaukee, Dr. G. A. Bading increased the quantity of garbage collected by approximately 62%, the corresponding increase of population being about 12%, and the increased cost of collection being about 17%. The effect of the

TABLE 19.—REFUSE PRODUCTION IN NEW ENGLAND, 1909, IN MANUFACTURING AND RESIDENTIAL CITIES

City	Population	Pounds per 1000 Population per Day			Percentage by Weight		
		Garbage	Ashes and rubbish	Total	Garbage	Ashes and rubbish	Total
Manufacturing cities:							
New Bedford	92,718	477	2939	3416	14.0	86.0	100.0
Lynn	87,166	538	3494	4032	13.3	86.7	100.0
Lawrence	83,096	256	2594	2850	9.0	91.0	100.0
Manchester	68,904	59	3141	3200	1.8	98.2	100.0
Taunton	33,678	173	971	1144	15.2	84.8	100.0
Averages	.....	301	2628	2929	10.3	89.7	100.0
Residential cities:							
Cambridge	103,531	987	4342	5329	18.5	81.5	100.0
Somerville	75,830	601	4232	4833	12.5	87.5	100.0
Malden	43,280	297	2690	2987	9.9	90.1	100.0
Everett	32,712	579	1473	2052	28.3	71.7	100.0
Newton	39,280	598	4989	5587	10.7	89.3	100.0
Averages	.....	612	3545	4157	14.7	85.3	100.0

Computed from Table No. 12 of Census Bureau Report, General Statistics of Cities, 1909, and with the following values:

1 cu. yd. garbage = 1200 lb. 1 cu. yd. rubbish = 200 lb.
1 cu. yd. ashes = 1350 lb. 1 cu. yd. ashes and rubbish = 1000 lb.

quality of the service is seen clearly in Chicago, when comparing the quantity of refuse produced in wards having better service with those in which the service is poorer (Table 21). During the period covered by the records, the superintendents in Wards 2, 15, 23, 31, and 24 were reported as giving the more efficient service.

5. Influence of the War.—At some newly constructed army camps, (1917), the production of garbage amounted to about 300 lb. per

Table 20.—Effect of Nationality on Production of Refuse in Chicago, 1912. Quantities in Pounds per Capita per Annum

Ward	Principal Nationality	Garbage	Ashes and rubbish	Totals	Weight of garbage, in pounds per cubic foot
		American			
2	American	161	905	1066	44.3
3	"	133	669	802	45.2
4	"	108	644	752	38.0
5	"	74	374	448	39.9
6	"	108	492	600	45.7
7	"	107	711	818	44.9
9	"	....	555	555	....
13	"	159	683	842	40.3
14	"	107	604	711	42.6
18	"	125	892	1017	35.9
21	"	118	1176	1294	38.7
23	"	144	810	954	37.9
25	"	146	568	714	37.5
26	"	136	670	800	37.6
29	"	55	340	395	40.4
30	"	126	582	708	45.6
31	"	143	530	673	40.8
32	"	113	570	683	38.0
33	"	122	422	544	37.9
34	"	104	570	674	41.9
35	"	126	477	603	37.6
Averages...	....	120.7	630.7	745.7	40.5
		Foreign			
1	Italian	87	978	1065	38.1
19	"	80	698	778	38.4
22	"	77	649	726	36.3
8	Polish	....	459	459	....
11	"	69	578	647	39.9
16	"	81	485	566	37.3
17	"	101	477	578	39.7
27	"	67	270	337	36.2
28	"	102	509	617	33.5
10	Bohemian	77	532	609	37.5
12	"	72	364	436	43.7
15	German	137	581	718	40.1
24	"	114	633	747	35.8
20	Russian	112	939	1051	36.9
Averages...............		90.5	582.3	666.3	39.5
Averages for American and Foreign..........		108.8	611.3	713.9	40.1

capita per year, or about 50% more than a natural city production. One reason for the increase was that all the garbage was actually collected, whereas, in many cities, the collection service sometimes does not reach the entire population. The producers of garbage in army camps are able-bodied men and large eaters, when compared with an

Table 21.—Results of Collection Service in Ten Chicago Wards, in 1912

Ward	Pounds per 1000 Population per Day		Number of Collections per Week			
			Garbage		Ashes and rubbish	
	Garbage	Ashes and rubbish	Winter	Summer	Winter	Summer
Wards with More Efficient Service						
2	518	2550	6	6	1–2	1
15	484	1600	2	2	1	1
23	465	2140	2	2	1	1
31	466	1465	1	2	1–2	1
24	440	1740	2	2–3	3	2
Averages.	475	1899	2.6	2.8–3.0	1.4–1.8	1.2
Wards with Less Efficient Service						
5	240	1020	2	3	2	2
11	222	1430	6	6	6	6
25	218	1720	2	2	2	2
27	218	743	1	2	3	2–3
29	178	938	2	2	2	2
Averages.	215	1170	2.6	3.0	3.0	2.8–3.0

average city population, including women and children. These facts also account somewhat for a larger quantity of garbage being produced.

During the war (1917–19) a number of unusual factors in the cities also tended to alter the normal production of refuse materials. Among these influences were the very active educational work of the United States Food Administration, the relatively high prices of all food

materials, and the difficulty, on the part of public officials, in securing sufficient and efficient help to remove thoroughly all the refuse usually collected. The net result of these factors was an average reduction of a little less than 10% in the per capita quantity of garbage collected. (Table 22.) With reference to the gradual per capita reduction of garbage in the army camps, see also Chapter IX, page 307.

Table 22.—Garbage Collected in Eighteen Cities During the Year Ending April, 1918, Compared with Collections for the Year Ending April, 1917. Showing Decreased Production During War Time

City	Population	Tons of Garbage		Pounds per Capita		1917–18 Collections compared with 1916–17, the latter taken as 100
		1916–1917	1917–1918	1916–1917	1917–1918	
Baltimore, Md.	593,000	37,915	24,685	128	117	91.5
Boston, Mass.	781,628	52,650	46,335	135	118	88.0
Bridgeport, Conn.	172,113	19,897	18,166	231	211	91.3
Cincinnati, Ohio	416,300	40,692	34,103	195	164	83.8
Cleveland, Ohio	674,073	59,708	55,466	177	164	92.9
Columbus, Ohio	220,000	20,393	17,295	185	157	84.8
Dayton, Ohio	155,000	16,621	15,677	214	202	94.3
Detroit, Mich.	750,000	72,785	64,270	194	172	88.3
Grand Rapids, Mich.	140,000	8,678	7,359	124	105	84.8
Indianapolis, Ind.	271,758	23,267	19,929	171	147	85.6
Los Angeles, Cal.	600,000	51,062	47,345	170	158	92.7
New Bedford, Mass.	118,158	10,162	8,774	172	148	86.3
New York, N. Y.	5,377,456	487,451	445,237	182	166	91.3
Philadelphia, Pa.	1,709,518	101,678	114,160	119	134	112.3*
Pittsburgh, Pa.	579,090	73,758	72,612	255	251	98.4
Rochester, N. Y.	275,000	30,782	25,926	224	189	84.2
Toledo, Ohio	220,000	23,971	22,180	218	201	92.5
Washington, D. C.	400,000	46,293	46,732	232	234	100.9
Totals and averages	13,453,094	1,177,763	1,096,251	175	163	93.1

* Doubtful.

The recent reduction in the quantities of garbage in our cities and the effect on the methods of disposal are discussed in an article by Mr. I. S. Osborn in the *American Journal of Public Health*, of May, 1918, from which most of the notes in the following paragraph have been taken:

One effect of the war on the production of city garbage was a general decrease in the quantity per capita; another was a decrease in its recoverable elements, and still another was a tendency to adopt disposal methods effecting better conservation of the valuable materials contained in the garbage. The increased prices of foodstuffs and the conservation movement started by the United States Food Administration naturally caused a decrease in the quantity of garbage produced. Reports from about sixty cities show that during 1917 there was an average decrease of from 12 to 15% in the quantity of garbage collected, though in a few cities there was an increase. In some cases the returns indicated an excessive decrease, but a study of the local conditions revealed the fact that in such cases less attention had been given to the collection, or that more private persons had been collecting the garbage for feeding hogs, because of the high price of pork. There was also a slight increase in the price of some of the by-products recoverable by reduction.

In Cincinnati, during the war, the production of garbage was reduced by about 16%, and there was a still greater reduction in the grease content.

The decrease in food waste is indicated more surely by the reduced quantity of grease recovered than by the actual quantities of garbage produced. Although the quantity of garbage may not continue to decrease, there is little doubt that the percentage of recoverable grease is gradually diminishing. Meats are the chief source of grease in garbage, and data from reduction works for a 9-month period in 1917 show a decrease of 30% in the grease recovered, as compared with a similar period in 1916, and the actual quantity per ton of garbage shows a reduction of about 15 per cent. This decreased production will probably continue for several years, due to the recent more frugal habits formed by the American people, who are gradually approaching European habits in preparing or conserving their food; and in some cities there may be a permanent re-adjustment of conditions relating to changed methods of disposal.

There has also been created a greater tendency to adopt disposal methods which conserve more of the valuable portions of garbage, and to abandon wasteful methods.

The method of disposal by feeding to hogs has spread to many cities. With pork at the recent prices, garbage, when disposed of by feeding, will produce from $7 to $8 in value for each ton. Thus, for communities where the garbage can be properly collected and controlled, no other method of disposal shows equally high returns.

Notwithstanding the decreased per capita quantity of garbage and grease, the larger cities may still find the reduction processes economi-

cal for some time. The decrease in the quantities of grease and tankage have been offset, to a large extent, by their increased values. The recent saving tendencies may nevertheless remain for some time, and the public will probably no longer waste as much as formerly through the medium of the garbage can.

The decrease in the quantity of garbage in St. Paul, Minn., is shown by the fact that, in 1916, 12,000 tons were collected, and only 7,215 tons in 1918. The general influence of the war is shown by the diagram, Fig. 6, taken from the *Municipal Journal and Public Works* of August 9th, 1919.

To ascertain the effect of high food prices in New York City on the three kinds of refuse, the Department of Street Cleaning computed the collected material on a monthly average for the Boroughs of Manhattan, Brooklyn, and The Bronx. Comparing 1916 and 1917, the garbage decreased 2114 cart loads, and the rubbish 4923 cart loads per month, whereas there was an increase of 4742 cart loads of ashes.

E.—PROPORTIONS OF CONSTITUENT MATERIALS

The relative proportions of garbage, ashes, and rubbish which make up the household refuse are particularly important, because of their deciding influence on the equipment required for the collection service and on the method of final disposal. The proportions vary in different communities, in geographical locations, and even in different districts of the same city, as already indicated. Cities in the warm climates of the South produce less ash; therefore the proportion of garbage and rubbish in the total refuse is greater. The seasonal variations have similar effects; the proportion of garbage, as well as its total quantity, is greater in summer than during other seasons. Also, the character of the population has its effect. Among the lower classes a separation of garbage, ashes, and rubbish is found difficult to obtain, and the recorded proportion of garbage is therefore less than in wealthier districts. When garbage is collected by one department and ashes and rubbish by another, the proportionate quantities of each may vary from one administration to another, as the efficiency of the collecting department increases or decreases. The variations in the relative quantities of these materials in house refuse shows the importance of knowing thoroughly the detailed conditions under which the materials are collected and the records are kept. These conclusions may be drawn from some of the tables already given.

For comparison with European information, it is fairly safe to say, according to Mr. George Watson, that English town refuse consists

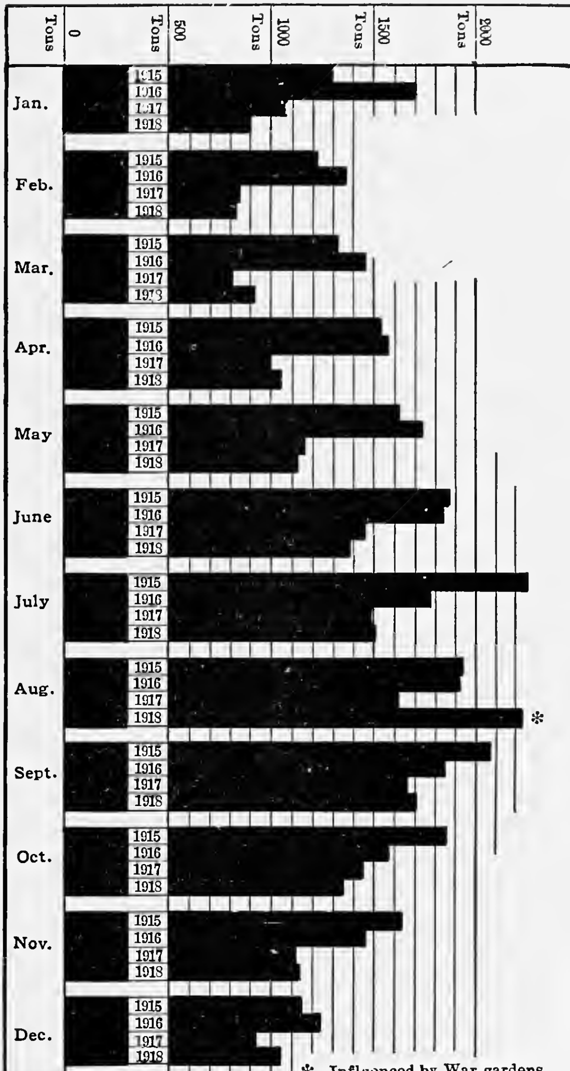

Fig. 6.—Garbage Collections in St. Paul, Minn., for Four Years, Showing the Influence of the War.

substantially of one-third combustible matter, one-third incombustible matter, and one-third moisture. Although the combustible matter in England, particularly in winter, includes much cinder, on the continent, excepting in Hamburg, cinder is almost entirely absent.

F.—UNIT WEIGHTS

The unit measures of house refuse are determined by a number of factors. Variations are due to the differences in the population, the season, and the character of the collection service.

Table 18 shows the weight of garbage for each ward in Chicago, in pounds per capita per annum. The figures are averages for 1912.

The weight of garbage per cubic yard, as collected in Milwaukee, is given in Table 23, together with the rainfall for July to December, 1910.

The figures in Table 23 are averages from about 5000 loads of garbage per month, each load of which was weighed. The increase in weight during the period of larger rainfall is about 8%. With individual loads, on very rainy days, the increase is greater, as shown by Table 24, containing the records of several individual loads in Milwaukee. A portion of the garbage recorded in this Table was wrapped in paper. The increase in weight of individual loads due to wet weather, therefore, may amount to more than 50%.

As the labor of handling refuse is more nearly proportionate to bulk than weight, it is well to record it also by bulk. Most of the information is now given by weight. It would be well, therefore, if more unit weights of the different materials collected were taken and reported, both for different week days and for different seasons, from which both bulk and weight could be ascertained. It would be still better if the labor were reckoned, not in dollars and cents, but in cubic yards or tons dealt with per man per hour.

The following data, showing the weight per cubic yard of different refuse materials, are taken from Hering's Milwaukee report: The weights were furnished by the city officials.

Material	Pounds per cubic yard
Garbage and rubbish mixed	1040
Ashes	1210
Rubbish	650
Manure (reported as "dry")	970

In some cases, special restrictions, placed on the householder by the collection department, will materially affect the weight per cubic

TABLE 23.—EFFECT OF RAINFALL ON GENERAL MONTHLY WEIGHT OF GARBAGE, IN MILWAUKEE, IN 1910
(5000 loads weighed per month)

Month	Rainfall during month, in inches		Weight per cubic yard, in pounds
July	2.84	Period of larger rainfall	930
August	2.75		950
September	1.71		990
Averages	2.43		957
October	1.24	Period of smaller rainfall	1000
November	1.63		890
December	0.46		770
Averages	1.11		887

TABLE 24.—EFFECT OF RAINFALL ON WEIGHT OF INDIVIDUAL LOADS OF GARBAGE AND ASHES, IN MILWAUKEE

Weather	Material	Number of individual loads weighed	Weight per cubic yard, in pounds
Very rainy	Garbage	4	1170
Clear	Garbage	4	740
Very rainy	Ashes	2	1560
Clear	Ashes	2	1440

TABLE 25.—WEIGHT OF REFUSE, NEW YORK CITY IN POUNDS PER CAPITA (U. S. CENSUS POPULATION)
(Data from Report by Parsons, Hering and Whinery, 1907)

Borough	1905					1906				
	Garbage	Ashes	Rubbish	Street sweepings	Total refuse	Garbage	Ashes	Rubbish	Street sweepings	Total refuse
Manhattan	222	1275	98	317	1912	217	1327	108	330	1982
The Bronx	121	757	49	188	1115	119	708	51	176	1054
Brooklyn	148	518	94	173	933	145	496	88	168	897
Queens	127	430	36	201	794	192	544	61	245	1042
Richmond	232	530	25	789	1576	256	561	40	804	1661
N. Y. City	185	920	88	261	1454	184	940	93	267	1484

yard of refuse as delivered. The Commissioner of Health in Minneapolis, having charge of garbage collection and disposal, has required that all householders shall drain the garbage and then wrap it in paper. This requirement is very generally observed. The weight of garbage in Minneapolis is recorded in the annual reports as being only 658 lb. per cu. yd. This low figure is due to the wrapping in paper. Trenton, N. J., has also advantageously adopted this practice.

Table 25 gives the weights per capita of the several kinds of refuse collected in the Boroughs of New York City during 1905 and 1906.

Parsons used the following conversion figures for New York City.

Garbage	1150 lb.	per cu. yd.	
Ashes	1350	"	"
Rubbish	200	"	"
Street sweepings	850	"	"

Special measurements were made in Rochester to determine the average weight per cubic yard of garbage, with the following results:

"The weights of six loads of garbage on October 27, measuring 3.23 cu. yd. each, are as follows:

	3,730 lb.
	4,080 lb.
	3,530 lb.
	3,450 lb.
	3,875 lb.
	3,895 lb.
Total	22,560 lb.

"This reduces to an average of 3760 lb. per load of 3.23 cu. yd., or 1164 lb. per cu. yd.

"The average weight per cubic yard of two loads of 3.23 cu. yd. each, on August 30, 1906, was 1174 lb. The average production of garbage per capita per year is 240 lb. The weight of rubbish is estimated at 200 lb. per cu. yd."

In a cold climate, frozen garbage and ashes weigh less per unit volume than when not frozen, because, generally, they do not pack so tightly in the wagon. Garbage, when delivered to a point of disposal after a long haul over rough roads, weighs more per cubic yard than otherwise, because of the settling and packing received while traveling. In a warm and moist climate, garbage, when tightly packed after delivery, weighs more than in a cold dry climate. In Miami, Fla., 1 cu. yd. has weighed as much as 1500 lb. Ashes and rubbish, when piled carelessly in yards or alleys, and infrequently collected, absorb moisture, become mixed with soil and dirt, and are generally heavier than when kept at the house in closed cans. Additional data regarding unit weights are given in Chapters XIV, XV, and XVI.

G.—COMPOSITION

The value of materials with reference to their final disposal is only to be obtained through a knowledge of their physical and chemical analyses, including their calorific value.

1. Physical Analysis.—A physical or mechanical analysis of refuse shows the quantities and proportions of garbage, fine ashes, clinker, glass, paper, wood, straw, metal, shoes, leather, etc. Most of these ingredients appear in all classes of refuse, but more particularly in ashes and rubbish. Such analyses of rubbish and mixed refuse are of special importance when it is proposed to sort out from the refuse the marketable constituents. The chief causes for the variation in the quantities of these ingredients are the character and habits of the population. Geographical location and season cause less variation. The quantities of discarded materials generally reflect the wastefulness or thrift of a community. Tables 26 to 29 inclusive give the physical analyses of refuse materials in a number of cities.

Table 30 is a summary of the physical analyses of Chicago refuse during one January in comparison with similar records in the Borough of Richmond, N. Y., during five Januarys.

In order to make comparable physical analyses of the ingredients for different communities, a standard method should be adopted. The procedure of the Bureau of Streets in Chicago, under the direction of Messrs. Fetherston, Osborn, and Greeley, as described on page 15, is here recommended. The following description of an analysis (Table 11) in Chicago is taken from a report by Mr. W. J. Galligan, Assistant Superintendent of Streets, as follows:

"Mixed ashes and rubbish, removed to dumps by the Chicago Bureau of Streets, were analyzed, from June 17 to Sept. 16, by selecting 60 representative loads from seven different zones into which the city was divided. The groups are based on similar existing conditions. * * *

"The segregation of the wards into the seven groups was based on the character of the residents as well as the class of buildings and their use.

"*Group A* is composed of business and manufacturing interests and consequently has only a small output of household refuse.

"*Group B* is made up of residences and high-grade apartment buildings, the homes of the wealthy. The help employed is wasteful, the ashes are not sifted, and the garbage output is above the average. Steam and hot water heat are used for the most part. The output of ashes is large in summer because hot water heaters are operated. Anthracite, semi-anthracite, or Pocahontas coal is the fuel used.

"*Group C* includes houses and flats or apartments occupied by the middle class. The residents are economical, and to a considerable extent sift their ashes and burn the cinders. Steam, hot water, and furnaces furnish the heat.

TABLE 26.—PHYSICAL ANALYSES OF RUBBISH OF A FEW CITIES

(Percentages by weight)

City	Year	Paper	Rags	Wood	Tins	Iron	Other metal	Bottles	Broken glass	Leather	Garbage	Authority
Cincinnati...	1909–10	40.3	6.7	7.2	15.9	2.5	......	6.3	11.0	2.4	7.6	State Board of Health Report, 1910
Cleveland...	1909–10	28.9	7.6	13.6	18.6	3.6	1.1	5.7	14.2	2.3	4.3	
Dayton.....	1909–10	16.4	6.2	17.0	26.3	5.1	1.3	8.4	12.7	3.0	3.4	
Washington..	1915	8.7	5.2	3.8	9.6	......	1.0	8.4	4.2	0.8	......	Osborn
London.....	1907	39.4	3.6	......	......	......	9.2	13.1	5.0	......	29.7*	Russell (Hering)
Berlin.......	1907	23.3	6.3	2.2	......	......	4.2	7.0	33.5	3.8	19.7*	Bohm and Grohn (Hering)

* Straw and leaves

During the summer season the ash output is from hot-water heaters, gas being used for cooking purposes. The output of garbage from this group is relatively small contrasted with that of group *B*.

"*Group D* is composed of houses and tenements occupied by the laboring class. These people are economical, heat by stove, sift their ashes, and use both bituminous and anthracite coal. They also burn such combustible refuse

TABLE 27.—PHYSICAL ANALYSES OF RUBBISH, IN WASHINGTON, D. C., NOVEMBER, 1914, TO AUGUST, 1915

(In percentages by weight)

Component parts	Nov., 1914	Dec., 1914	Jan., 1915	Mar., 1915	May, 1915	June, 1915	July, 1915	Aug., 1915
Newspaper	10.4	17.8	19.5	16.1	15.6	17.2	17.0	16.0
Manila paper	6.6	12.7	7.0	9.5	8.7	7.3	12.1	13.4
Cardboard	0.8	9.4	11.7	10.5	9.7	6.9	10.9	12.8
Books, etc	4.4	3.0	2.4	2.4	3.3	3.2	1.4	5.6
Mixed paper	16.6	4.4	3.1	5.0	4.6	2.8	2.4	2.6
Rags	5.9	3.7	4.5	5.2	7.2	4.3	5.0	5.7
Wood	1.2	7.4	1.4	2.8	2.6	4.1	2.6	4.1
Leather	1.5	0.2	0.4	0.7	1.2	0.2	1.0	1.1
Rubber	0.3	0.3	.....	0.3	0.5	0.0	.....	.....
Screenings	.....	4.6	18.5	13.4	10.4	18.6	12.3	11.1
Tinware	10.2	7.3	11.7	13.6	8.8	6.6	5.6	6.4
Enamelware	0.4	0.4	0.1	0.4	0.3	5.0	.....	0.1
Metals	1.8	0.6	0.3	0.8	1.3	1.1	0.8	1.5
Bottles	11.0	8.1	7.7	9.0	7.7	8.3	8.4	7.2
Broken glass	3.8	3.5	4.0	4.7	5.2	4.3	4.8	3.5
Excelsior	.....	0.7	0.3	0.8	0.7	0.1	0.7	.....
Matresses, etc	5.2	1.1	.....	.....	0.3	0.0	0.7	0.1
Matting	3.1	0.8	0.1	0.3	1.6	1.5	1.4	.....
Linoleum	0.7	.....	.....	.....	0.3	0.1	.....	0.1
Straw	.....	.....	0.4	.....	.....	0.0	.....	.....
Dirt	16.1	14.0	6.9	4.5	10.0	8.4	11.5	8.7
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

as is available for heating purposes. During the summer season they use gas, bituminous coal, and wood as fuel for cooking.

"*Group E* is made up of tenement houses occupied by the working classes who are foreign and still use their native language. These people are careless about littering the streets and alleys, and fail to comply with notices served to correct violations of city ordinances. Analyses show them to be careless also about separating garbage from other refuse. They are not wasteful, however, but, on the contrary, very saving in every way possible. Stove heat is em-

ployed, about 75% of the coal burned being bituminous and of the cheapest kind. The resulting ash is of little calorific value. In seven of the nineteen

TABLE 28.—PHYSICAL ANALYSES OF RUBBISH, NEW YORK CITY

(In percentages by weight)

Component parts	Percentage Picked Out as Marketable				Percentage of Total Composition		
	City of New York			Boston. Atlantic Avenue Station (Morse)	New York. (Craven) *	London. (Russell) *	Berlin. (Bohm and Grohn) *
	Delancey Slip Station (Parsons)	Thirtieth Street dump (Stearns)	Forty-seventh Street dump (Stearns)				
Stoneware	......	......	......	......	......	5.0	33.5
Rags	4.60	......	2.78	0.76	15.5	3.6	6.3
Rubber	......	......	......	......	0.1	......	......
Leather	......	......	......	......	1.8	......	3.8
Straw	......	......	......	......	......	29.7	19.7
Wood	......	7.3	8.91	......	1.4	......	2.2
Metals	0.86	1.3	4.10	0.12	3.3	9.2	4.2
Glass	......	1.4	0.76	0.35	2.9	13.1	7.0
Bagging	......	......	0.39	......	......	......	......
Carpets	......	......	0.57	......	......	......	......
Shoes	......	......	0.39	......	......	......	......
Hats	......	......	0.03	......	......	......	......
Rope and string	......	......	0.23	0.12	......	......	......
Paper	25.40	33.3	......	23.90	75.0	39.4	23.3
Newspaper	......	......	10.94	......	......	......	......
Manila	......	......	2.64	......	......	......	......
Pasteboard	......	......	10.35	......	......	......	......
Mixed	......	......	6.16	......	......	......	......
Books	......	......	0.55	0.24	......	......	......
Total marketable	30.86	43.3	48.80	25.49			
Total worthless	69.14	56.7	51.20	74.51			
Totals	100.00	100.00	100.00	100.00	100.0	100.0	100.0

* International Engineering Congress, Am. Soc. C. E., 1904. Paper by Rudolph Hering. (From "Municipal Refuse," by H. de B. Parsons)

wards a large amount of wood is used as fuel. During the summer season wood and coal are used for cooking purposes.

"*Group F* is composed of the homes of a mixed population of native white, foreign born, and colored people, also of cheap rooming houses occupied by persons who do light housekeeping. They are careless about littering the

TABLE 29.—PHYSICAL ANALYSIS OF 21,034 LB. OF REFUSE, COLLECTED FROM ALL PARTS OF TORONTO, ONT., OCTOBER, 1914

(From *Engineering News-Record*, February 7, 1918, p. 259)

Classification	Weight		Volume		Pounds per cubic foot
	Pounds	Percentage	Cubic feet	Percentage	
Glass and crockery......	771.25	3.52	22.30	1.90	28.2
Metals................	81.50	0.40	7.50	0.52	10.9
Paper and cardboard...	4,653.00	22.12	682.40	47.58	6.8
Tins..................	398.25	1.90	49.55	3.47	8.0
Rags..................	420.75	2.01	42.53	2.98	9.9
Bones.................	150.00	0.72	4.70	0.33	31.9
Vegetable matter.......	10,185.00	48.53	390.72	27.21	26.1
Bread.................	156.75	0.75	11.06	0.89	14.1
Fish..................	240.50	1.15	6.10	0.41	39.4
Wood, boxes, and baskets	235.50	1.12	40.60	2.89	5.8
Linoleum..............	113.25	0.54	17.29	1.27	6.6
Grass, flowers, and weeds	187.75	0.89	25.91	1.80	7.2
Shoes.................	92.50	0.44	6.66	0.48	13.9
Sawdust and dirt.......	2,196.00	10.44	66.79	4.66	32.8
Ashes.................	1,079.00	5.13	31.20	2.18	34.6
Excelsior, straw........	73.00	0.34	20.46	1.43	3.6
Totals and averages...	21,034.00	100.00	1430.77	100.00	14.7

TABLE 30.—PHYSICAL ANALYSES OF ASHES AND RUBBISH COLLECTED IN JANUARY. NEW YORK AND CHICAGO

(Percentages by weight)

	Fine ash	Coal and cinders	Clinker	Glass	Rubbish	Garbage
Borough of Richmond, New York, average of five Januarys........	53.5	27.1	2.9	6.6	9.9	0.00
Chicago, one January...	49.88	34.00	11.59	1.84	1.70	0.99

streets and alleys, and separation of garbage. Wood and bituminous coals are used for fuel during all seasons of the year.

"*Group G* (not included in the accompanying table) is made up of the

homes of a mixed population of American and foreign-born persons ranging from the middle to the laboring class. No separation of garbage from other refuse is asked, owing to the inaccessibility of these districts to the reduction plant. All grades of coal and wood are used for fuel.

"In one of the 60 loads no ashes were found. Seven loads in group *G* were not used in the table owing to the non-separation of garbage from other refuse. The loads averaged 5 cu. yd. each.

"In certain wards there were proportionately larger amounts of combustible refuse than in others, due to ward burners not being operated and to the frequency of service given, whether daily, twice a week, or weekly. In many localities the residents have portable rubbish burners. In a large number of apartment buildings there are installed crematories in which both garbage and rubbish are consumed. This is particularly true during the winter season.

"The total weight of rags in the sixty loads analyzed was 2640 lb. They were obtained largely in wagons from ward groups *B* and *C*, representative of the wealthy and middle class. In wagons of groups *D* and *E* but small quantities were found. Rag pickers, with their carts of about a cubic yard capacity, flourish in the former groups.

"*Old Newspapers.*—It is difficult to secure a reasonably accurate estimate of the output of newspapers rejected by the public. Janitors, generally, save, bundle and hold papers until they acquire a considerable quantity, which they sell to paper or junk dealers. Both in the case of elevated railroads and steam roads carrying suburban passengers, at each terminal the papers are gathered, baled and sold in car-load lots. The total circulation of the daily morning and evening papers is 1,265,400, weighing 1660 tons. Based upon these figures the annual tonnage would be nearly 520,000 tons. Added to this are the Sunday editions, bringing the total very close to 600,000 tons per year of this sort of refuse.

"Peddlers canvass the districts embraced in ward groups *B* and *C* offering brooms and other household articles in exchange for fairly good old shoes. These are sold to a class of cobblers and small dealers who repair and sell them at a small price. Discarded shoes from the other groups are of practically no value, having been worn beyond repair.

"Little metal of any kind was obtained in the loads analyzed. Cast iron and scrap iron were to a small degree in evidence. This class of waste is generally sold by householders and janitors to junk dealers.

"Rubbish in the streets and in the alleys is picked over by a class of men who gather anything that has a ready commercial value. The number of men who are thus employed is large; nearly all junk dealers are ready to furnish them with carts or bags. The work is systematized, the men working in definite districts.

"*Recovery of Valuable Matter.*—Trade waste is a term applied to refuse discarded by factories, manufacturers, hotels, and other places of business, which is not removed by the city. From this class of refuse, practically everything of value is extracted by the owner, janitor, or a contractor. Certain owners or agents have the cinder output removed from their premises without cost under private contract, by including their salable refuse. Garbage from

hotels, cafés, and restaurants, rich in meat grease and bone, is of commercial value and is sold or given in exchange for soap or other articles of value.

"In the sixty loads analyzed, fine ash, cinder, and clinker comprised 49.3% by weight of the whole, and rubbish the remainder. Rubbish, excluding garbage, was 29.8% of the whole. The weight of ashes per cubic yard was 1185 lb., and the percentage of combustible material was 58.3. The material having a commercial value was 14.8%.

"The weight per cubic yard of rubbish is considerably higher than that of other cities, due to its containing yard cleanings and larger amounts of garbage. The term yard cleanings used in the Chicago classification of waste does not appear in the reports of other cities. This material remained in the screen in the analyzing process and was separated from the cinders by picking."

In some cases it is desirable to separate the fine ash from the ashes when collected, leaving a larger proportion of cinder or unburned carbon, and larger interstitial air space. By doing this, combustion is increased, the necessary capacity of the furnaces is reduced, and a more serviceable burning mixture is obtained. The cost of screening, however, sometimes makes it uneconomical.

In some cities, especially along the Pacific Coast, the refuse contains many tin cans. A mechanical analysis should be made, to show their quantity, as their presence is an important item for consideration in several methods of disposal.

Tests have been made at Milwaukee and New York to determine how much moisture can be drained or pressed out of garbage. The tests at Milwaukee, made by Professor Sommer, extended over 24 hours. Different quantities of garbage were placed in a salt barrel, and the quantity of water draining out was recorded. The results of this test are shown in Table 31. The maximum quantity of moisture which drained out under a pressure of 24 in. of garbage was 9.33% of the original weight.

Compression tests were made by the Lederle Laboratories for the Parsons, Hering, Whinery report to New York City. The tests and results (Table 32) are given in the report as follows:

"One cubic yard of garbage was placed in a cylindrical vessel, 3 ft. in diameter and 4 ft. deep. Weights of 438, 1,059, 1,694, and 2,330 lb., corresponding, respectively, to 60, 150, 240, and 330 lb. per sq. ft., were placed on the garbage, and the water drawn off at recorded intervals of time and measured.

"The second test produced so much more liquid than the first that it was thought advisable to subject garbage collected on a Monday to the initial test of 60 lb. pressure. The result is given in the third test."

Further data referring to physical analyses may be found in Chapters XIV, XV, and XVI.

2. Chemical Analysis.—The chemical analysis of refuse is difficult to obtain accurately. It should include a determination (1) of the ingredients in refuse which are valuable in soil fertilizing; (2) the quantities of grease which may be recovered; and (3) the quantities of carbon and hydrogen capable of oxidation to produce heat. It should determine, also, the moisture in the refuse material, the quantity of true ash, and the calorific value of the materials.

TABLE 31.—DETERMINATION OF FREE MOISTURE IN GARBAGE, MILWAUKEE, 1907

Date	Quantity of Garbage		Quantity of Water Drained Out	
	Weight, in pounds	Heights in barrel, in inches	In pints	Percentage by weight of original garbage
September 17th...	50	8	0.33	0.67
September 18th...	100	16	7.50	7.50
September 19th...	150	24	14.00	9.33
September 20th...	200	32	15.00	7.50

The difficulty in obtaining these data with fair accuracy is due to the difficulty of securing representative samples, because the materials vary from one year to another, from season to season, and according to the localities where collected. Most analyses do not cover periods of more than a few weeks; therefore, the results are not usually truly representative, but only show the composition under stated conditions.

Garbage at Milwaukee, Wis., was analyzed in 1907 by Professor Sommer, and in 1910 by Greeley; the results of the two analyses are as follows:

Source	Percentage by Weight			
	Moisture	Volatile matter	Fixed carbon	Ash
Sommer................	78.0	......	8.4	13.6
Greeley................	70.6	17.6	4.1	7.7

These analyses show the importance of securing proper representative samples, as the portion analyzed by Professor Sommer appears

TABLE 32.—LIQUID SQUEEZED FROM NEW YORK GARBAGE BY PRESSURE
(Parsons, Hering, Whinery Report, 1907)

	Pressure, in pounds per square foot	Time from Start of Test		Quantity of Liquid Squeezed Out from Start of Test	
		Hours	Minutes	Pounds	Ounces
First Test:	60	....	15	....	....
Monday's garbage collected Tuesday; bulk, 1 cu. yd.; total weight, 677 lb.	60	....	45	....	....
	60	7	15	....	3
	150	17	....	4	....
	240	6	....	7	8
	240	30	....	19	....
	330	5	30	24	8
Totals..........	....	59	45	47	11
Second Test:	150	....	15	21	....
Sunday's garbage, collected Monday; bulk, 1 cu. yd.; total weight, 1122 lb.	150	....	30	32	....
	150	1	....	40	....
	150	5	....	68	....
	150	6	30	73	....
	150	35	30	82	....
	240	....	15	1	8
	240	....	30	4	....
	240	1	....	6	8
	240	3	30	14	8
	240	6	30	20	8
	240	24	30	54	....
	330	....	15	1	4
	330	....	30	2	8
	330	1	....	5	8
	330	3	....	14	8
	330	24	....	43	....
	330	27	30	50	12
Totals..........	....	87	30	186	12
Third Test:	60	....	15	21	....
Sunday's garbage, collected Monday; bulk, 1 cu. yd.; weight, 1333 lb.	60	....	30	32	....
	60	1	....	45	....
	60	3	....	67	....
	60	6	....	86	....
	60	17	....	103	....
Totals..........	....	17	....	103	....

to have included substances containing a comparatively large proportion of ash.

Most refuse materials contain some ingredients which are useful in the fertilization of soil. This is particularly true of manure, as pointed out in Chapter XII, but garbage and ashes also contain small quantities of plant food. The chief elements of fertilizing value are phosphoric acid, ammonia, and potash. Coal ashes contain a very small quantity of potash, and therefore have only a slight fertilizing value. Garbage, on the other hand, has a decided value as a fertilizer for poor or sandy soils. Yet this value is less than is shown by the analyses, or than is popularly supposed, because the animal and vegetable matters must first be decomposed before they are available for plant food. The grease content in garbage is even detrimental to its immediate value as a fertilizer, as it tends to clog or "fat" the soil, thus preventing the necessary penetration of air.

In the reduction method of garbage disposal grease is extracted and water is driven off. The fertilizing elements are concentrated into a dry residue called tankage. In some cases, special analyses have been made in order to show the value of garbage for this method of disposal. The quantity of grease contained in garbage varies from about 1 to 7% of the weight of the raw material, and the residual tankage varies from 10 to 20%.

Although the foregoing analyses are not extensive enough to show fixed variations in the chemical composition due to the location or season, or to the character of the population, nevertheless, the resulting differences certainly exist. In warm seasons and in warm climates less meat and more vegetables are eaten. In such cases, the quantity of grease in the garbage is less, because it is derived principally from the animal matter. In 1910, in Columbus, Ohio, where the garbage is treated by reduction, the grease recovery in summer was 1.1%; but in winter it amounted to 1.5%. Partly on this account, reduction works in southern cities, as a rule, have not been profitable.

The quantities of grease, in percentages of the garbage, for several cities have been as follows:

City	1914	1915	1916	1917	1918	1919
Detroit[1].......	....	....	2.4	3.0	2.9	....
Cleveland......	2.95	2.81	3.06	2.83	2.36	2.55
Columbus......	2.74	2.21	3.08	2.3	2.16	....
Minneapolis....	....	....	....	1.0[2]	....	....

[1] Data for 4 months of each year.

[2] Average from all wards.

To design refuse incinerators properly, the analyses of the refuse materials should show the content of carbon, hydrogen, water, fine and true ash, volatile matter, and the British thermal units. These elements are required in order to compute the heat value, the quantity of clinker, and the cross-sectional areas necessary for the furnace ducts and flues. The hydrogen may assist in estimating the calorific value of the material. Tables 33 to 36 give analyses of refuse showing these constituents.

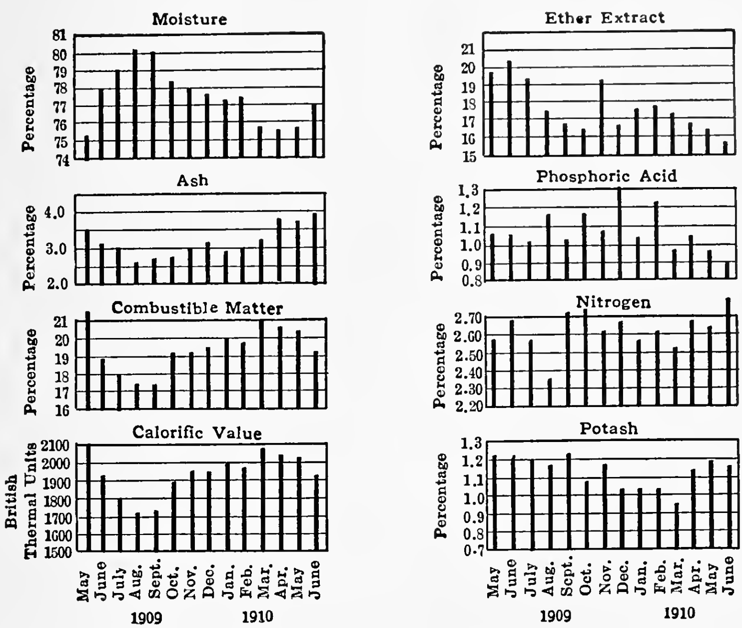

FIG. 7.—Average Monthly Variation in Consituents of Garbage in Four Ohio Cities, and Calorific Values.

NOTE.—Averages, May to August, 1909, for Cleveland, Columbus, and Dayton; averages, September, 1909, to June, 1910, for Cincinnati, Cleveland, Columbus, and Dayton.

Fig. 7 shows the average monthy variation in percentages of moisture, ash, combustible matter, calorific value, ether extract, phosphoric acid, nitrogen, and potash in the garbage of four Ohio cities.

Table 37 presents chemical analyses of the garbage in Cincinnati, Ohio, at various times from March to December, 1917, together with averages for each month.

TABLE 33.—PROXIMATE MONTHLY ANALYSES AND CALORIFIC VALUES OF CONSTITUENTS OF MIXED REFUSE, IN CLIFTON DISTRICT, BOROUGH OF RICHMOND, NEW YORK CITY.

(Figures give percentages by weight, except British thermal units. J. T. Fetherston, 1907.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Averages
FINE ASH													
Moisture	4.8	5.2	5.0	5.4	3.5	2.9	1.5	1.8	3.2	6.0	6.0	6.1	4.1
Volatile combustible	1.4	1.3	1.2	1.0	0.9	0.6	0.5	0.5	0.4	0.9	1.2	1.3	1.1
Fixed carbon	7.6	7.4	6.9	5.6	5.1	3.6	2.8	2.7	2.3	5.2	6.5	7.0	5.9
Ash	25.7	24.8	23.0	18.9	17.0	12.0	9.4	9.2	7.7	17.4	22.0	23.4	20.0
British thermal units per lb.	1126	1087	1008	827	744	525	413	401	337	763	964	1027	875
CLINKER													
Moisture	0.1	0.2	0.2	0.2	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.1
Volatile combustible	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fixed carbon	0.3	0.3	0.3	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.3	0.3	0.3
Ash	2.0	2.1	1.8	1.6	1.6	1.1	1.0	0.8	0.8	1.3	2.0	2.1	1.7
British thermal units per lb.	45	47	42	36	38	26	24	18	18	30	46	47	40
GLASS, METAL, ETC.													
Moisture	0	0	0	0	0	0	0	0	0	0	0	0	0
Volatile combustible	0	0	0	0	0	0	0	0	0	0	0	0	0
Fixed carbon	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	6.1	6.7	6.5	6.5	8.5	9.2	10.5	8.5	10.8	7.6	7.1	6.3	7.5
British thermal units per lb.	0	0	0	0	0	0	0	0	0	0	0	0	0

Coal and Cinders													
Moisture	2.6	2.5	2.7	2.6	1.6	1.7	0.8	0.7	1.8	1.7	2.4	2.6	2.0
Volatile combustible	0.6	0.6	0.6	0.4	0.4	0.3	0.3	0.2	0.2	0.4	0.5	0.6	0.5
Fixed carbon	14.8	14.7	13.6	9.5	8.5	7.0	5.5	5.3	4.9	8.9	12.0	13.8	11.2
Ash	4.8	4.8	4.5	3.1	2.8	2.3	1.8	1.8	1.6	2.9	3.9	4.5	3.7
British thermal units per lb.	2342	2331	2184	1509	1351	1115	878	844	777	1419	1903	2196	1779
Garbage													
Moisture	13.8	13.1	16.3	20.1	20.5	27.5	31.3	31.3	31.2	23.4	15.8	13.7	21.2
Volatile combustible	5.4	6.6	6.7	9.1	11.0	11.1	12.5	15.2	14.2	9.5	7.4	6.7	7.2
Fixed carbon	1.2	1.5	1.5	2.0	2.5	2.5	2.8	3.4	3.1	2.1	1.7	1.5	1.6
Ash	0.8	1.0	1.1	1.5	1.8	1.8	2.0	2.4	2.3	1.5	1.2	1.1	1.1
British thermal units per lb.	823	762	777	1054	1278	1293	1447	1755	1639	1101	862	777	831
Rubbish													
Moisture	1.7	1.8	1.6	2.2	2.8	3.5	2.4	2.6	4.7	4.0	2.3	2.3	2.7
Volatile combustible	4.4	3.8	4.4	5.7	7.8	8.8	10.3	9.4	7.4	6.3	5.4	4.6	5.7
Fixed carbon	1.1	0.9	1.1	1.4	1.9	2.2	2.6	2.4	1.9	1.5	1.3	1.1	1.4
Ash	0.8	0.7	0.8	1.0	1.4	1.6	1.8	1.6	1.3	1.1	0.9	0.8	1.0
British thermal units per lb.	506	411	474	609	835	949	1447	1013	800	680	574	488	616
Totals													
Moisture	23.0	22.8	25.8	30.5	28.5	35.7	36.0	36.5	41.0	33.1	76.6	24.9	30.1
Volatile combustible	11.8	12.3	12.9	16.2	20.1	20.8	23.6	25.3	22.2	17.1	14.5	13.2	14.5
Fixed carbon	25.0	24.8	23.6	18.7	18.3	15.5	13.9	13.9	12.3	18.0	21.8	23.7	20.4
Ash	40.7	40.1	37.7	34.6	33.1	28.0	26.5	24.3	24.5	31.8	37.1	38.2	35.0
British thermal units per lb.	4732	4638	4485	4035	4246	3908	3874	4031	3571	3993	4349	4535	4141

As a general approximation of fuel values, it has been found that 1 lb. of coal is equaled by the value which, under favorable conditions, can be obtained from 8 to 12 lb. of unsorted refuse, including domestic ashes.

Mr. J. T. Fetherston, in 1908, in a paper read before the Society of Chemical Industry, New York Section, gave a chemical analysis (Table 38) of an average sample of the three principal components of refuse, together with the calculated calorific values and those determined by tests. He also shows, in diagrammatic form (Fig. 8), the

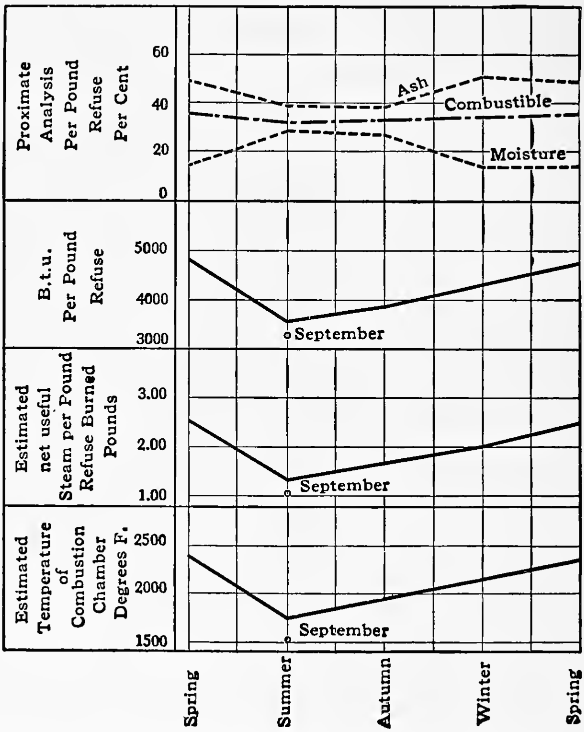

FIG. 8.—Seasonal Variation in Mixed Refuse Incineration, West New Brighton.

seasonal variation in the mixed refuse at the West New Brighton incinerator. From this diagram it will be seen that the ash is high in winter, and the water content of household refuse increases with the proportion of garbage in summer. The second division of the diagram shows that the summer refuse is low in calorific power, and that September is the critical time for burning the mixed waste. Sep-

tember is also indicated as the critical time for producing steam from mixed refuse, and is the time when the lowest temperature of combustion may be expected. In this case, however, the temperature would be high enough to ensure the complete decomposition of the gases, and thereby prevent nuisance.

TABLE 34.—MONTHLY VARIATION IN CHEMICAL COMPOSITION OF GARBAGE IN WASHINGTON, D. C., IN 1915

Month	Number of tons collected	Moisture	Combustible	Ash	Ether extract	Potash as K_2O	Phosphoric acid as P_2O_5	Nitrogen
January......	3,745	74.2	21.7	4.06	5.29	0.29	0.57	0.67
February.....	3,283	72.0	24.4	3.22	5.95	0.25	0.47	0.77
March.......	3,548	70.2	26.0	3.73	6.88	0.25	0.41	0.73
April.........	3,829	68.5	27.5	3.96	7.16	0.29	0.61	0.96
May.........	3,969	72.0	23.9	4.16	6.56	0.33	0.47	0.82
June.........	4,002	74.2	21.8	4.42	4.97	0.31	0.32	0.61
July.........	5,266	79.7	17.6	2.67	3.44	0.31	0.27	0.46
August.......	8,341	78.6	18.5	2.89	3.82	0.23	0.27	0.54
September....	5,330	75.5	21.1	3.37	4.36	0.23	0.27	0.61
October......	4,607	76.4	20.7	2.89	4.15	0.22	0.20	0.64
November....	3,930	72.8	23.3	3.89	5.03	0.29	0.11	0.70
December....	3,846	72.2	23.5	4.28	5.96	0.32	0.74	1.03
Total.....	51,718	....	....	....	....	....	....	....
Averages..	.....	73.8	22.5	3.63	5.12	0.28	0.39	0.71

Mr. B. F. Welton is the authority for the following calorimeter test and proximate analysis of mixed refuse at West New Brighton, N. Y., made in 1906.*

1. The materials in the sample were:	Garbage.........	53.4%	by weight
	Coal and cinders..	27.0%	"
	Rubbish.........	19.6%	"
2. The proximate analysis showed:	Moisture........	45.1%	
	Volatile matter...	26.6%	
	Fixed carbon.....	23.8%	
	Ash.............	14.4%	
3. Proximate calorific values per lb.:	Original sample...	4300 B.t.u.	
	Dry sample......	7900 "	
	Combustiblealone	10630 "	

* *Transactions*, Am. Soc. C.E., Vol. LX (1908).

TABLE 35.—CHEMICAL ANALYSES OF REFUSE MATERIALS

City	Year	Material	Percentage by Weight				Reference
			Moisture	Volatile matter	Fixed carbon	Ash	
West New Brighton	1905–06	Garbage	73.26	16.89	4.71	5.14	Fetherston
Milwaukee	1910	Garbage	70.6	17.6	4.1	7.7	Greeley
New York City	1907	Garbage	68.50	22.69	3.73	5.08	Parsons, Hering, Whinery Report
Washington	1916	Garbage	73.85	22.52	....	3.63	Osborn
West New Brighton	1905–06	Ashes	1.34	3.73	55.0	39.93	Fetherston
Milwaukee	1910	Ashes	18.0	5.8	23.3	52.9	Greeley
New York City	1907	Ashes from dump	1.07	17.55	21.52	59.86	Parsons, Hering, Whinery Report
New York City	1907	Household ashes	0.96	6.31	25.68	67.05	Parsons, Hering, Whinery Report
Washington	1916	Cinders	2.05	3.53	51.19	45.30	After screening out the dust
		Dust	4.55	5.09	15.99	78.27	Cinders screened out. Osborn
West New Brighton	1905–06	Rubbish	5.78	65.66	14.69	13.87	Fetherston
Milwaukee	1910	Rubbish	24.9	36.3	14.9	23.9	Greeley
New York City	1907	Rubbish	11.5	40.4	40.5	7.6	Parsons, Hering, Whinery Report
Washington	1916	Rubbish	6.7	73.2	7.9	12.9	Osborn

It is obviously important that chemical analyses of refuse should be made with sufficient uniformity to permit of securing fair comparisons. The procedures described below are recommended by Dr. Arthur Lederer, formerly Chief Chemist of the Sanitary District of Chicago.

TABLE 36.—CHEMICAL ANALYSIS AND CALORIFIC VALUE OF DRY RUBBISH, NEW YORK CITY.

Determinations made by D. C. Johnson

(Data from Parsons, Hering, Whinery Report, 1907)

Average of two chemical analyses of dry rubbish delivered at Delancey Slip Station, in December, 1905		Calorific value of four samples of dry rubbish delivered at Delancey Slip Station, in December, 1905	
	Percentage		B.t.u.
Nitrogen	1.00	Sample No. 1, by Mahler calorimeter	7810
Hydrogen	5.60	Sample No. 2, by Mahler calorimeter	7750
Carbon	45.81	Sample No. 3, by Mahler calorimeter	7580
Oxygen	39.01	Sample No. 4, from chemical analysis	7150
Ash	8.58		
Total	100.00		

The first important proceeding is the obtaining of the sample. The number of analyses depends on whether two or three will be sufficiently representative of the community at large, or whether a larger number are required, in order to show characteristic differences in the various districts of the city.

Two shovels full should be taken from each of ten to twenty wagon loads, and should be well mixed on a smooth, clean, and practically water-tight surface. The pile should be halved and quartered, and each quarter should again be thoroughly mixed. The sample for the analyses should be taken from the final quarter.

If garbage alone is to be sampled, portions from different parts of the final quarter should be selected, placed in a chopping bowl, beaten up, and comminuted, before the final sample is selected. For shipping the samples to the laboratory, 2-qt. jars are convenient. Dr. Lederer says:

a. Determination of Moisture.—A determination of the moisture content of refuse is essential for all analyses, irrespective of the final disposal method.

The moisture may be determined by exposing a large (several pounds) weighed portion of well-mixed refuse to dry heat (as over an incinerator) for

TABLE 37.—CHEMICAL ANALYSES OF GARBAGE IN CINCINNATI, OHIO

(From Report of Department of Health, 1918)

Month, 1917	Number of loads sampled	Number of analyses made	Percentage of moisture	Percentage on Dry Basis				Percentage on Raw Basis			
				Ether extract	Potash as K_2O	Phosphoric acid as P_2O_5	Nitrogen	Ether extract	Potash as K_2O	Phosphoric acid as P_2O_5	Nitrogen
March...........	479	8	72.75	17.75	0.84	2.44	2.85	4.84	0.23	0.66	0.78
April.............	571	8	73.58	17.91	0.91	1.95	2.81	4.74	0.24	0.52	0.74
May..............	386	5	75.30	17.48	1.12	1.98	2.91	4.33	0.28	0.49	0.72
June.............	419	5	76.90	18.09	1.22	2.31	2.91	4.19	0.28	0.53	0.68
July.............	342	4	78.78	18.02	1.47	1.75	2.90	3.84	0.31	0.37	0.62
August...........	373	5	76.44	16.04	1.26	2.02	2.88	3.78	0.29	0.47	0.68
September........	138	2	76.75	15.42	1.30	2.32	2.81	3.59	0.30	0.54	0.65
October..........	208	3	75.43	16.02	1.19	2.44	2.86	3.94	0.30	0.60	0.71
November........	226	4	73.10	16.34	1.02	1.72	2.65	4.39	0.27	0.47	0.71
December	115	2	71.40	16.72	1.00	2.75	2.72	4.78	0.28	0.80	0.78

several days until the weight has become constant. If the determination is made in the laboratory, take about 1000 grams of well-mixed refuse and rapidly reduce it in a grinding machine to a fine powder, so that it will pass through a sieve having circular holes of one millimeter (0.0394 in.) in diameter. In case the sample cannot be ground, reduce it otherwise to as fine a state as possible. Before evaporation can reduce the moisture, determine this at once by heating two grams (or five grams, if the sample is very coarse) for 5 hours in a water oven at the temperature of boiling water. The loss of weight measures the moisture.

TABLE 38.—CHEMICAL ANALYSES OF NEW YORK CITY REFUSE

Constituents	Percentages of Refuse Materials, by Weight		
	Garbage	Coal ashes and cinders	Rubbish
Carbon	43.10	55.77	42.39
Hydrogen	6.24	0.75	5.96
Nitrogen	3.70	0.64	3.41
Oxygen	27.74	2.37	33.52
Silica	7.56	30.01	6.49
Iron oxide and alumina	0.41	8.98	2.03
Lime	4.26	1.21	2.26
Magnesia	0.28	Trace	0.57
Phosphoric acid	1.47	None	0.10
Carbonic acid	0.59	None	1.49
Lead	0.20	Trace	0.52
Tin	Trace sulphides		Trace
Alkalies and undetermined	4.45	0.27	1.21
Calorific Values, in British Thermal Units			
Calculated from above analyses	7970	8382	7250
Averages of calorimeter determinations	8351	8510	7251

These chemical analyses are of dry composite samples of garbage, coal ashes and cinders, and rubbish, taken in 1905 and 1906.

In order to prepare the sample for the determination of the other chemical constituents, it is advisable to air-dry a large portion (80 to 100 grams) of the finely powdered sample, by exposing it to a temperature of 80 degrees Centigrade until the powder feels dry between the fingers. Determine the moisture content of the air-dried material in the same manner as given above, and put it into a weighing flask for further determinations.

b. Ash and Volatile Matter.—Ignite a convenient portion (about 2 grams of the air-dried material) in a nickel dish, and burn until free of carbon at the lowest possible heat. Heat to low redness and weigh. The residue, calculated by percentage on a completely dried basis, represents the ash; the difference represents the volatile matter, including the carbon.

c. Carbon and Hydrogen.—These constituents are determined by what is called the "elementary" analysis. A detailed description of this process can be found in Fresenius' "Quantitative Chemical Analysis," Vol. 2, page 56; and Stillman's "Engineering Chemistry," third edition, page 105. The following short description of this procedure will here suffice: The combustion apparatus consists of a set of Bunsen burners over which a combustion tube is suspended. The combustion tube is approximately 70 centimeters long. Into one end of the tube place granulated cupric oxide for a distance of about 30 centimeters. Place the tube in a combustion furnace, connect it with a drying apparatus at the point where the air current enters the tube. Connect the other end with a **U** tube filled with granulated calcium chloride. The **U** tube is connected with an aspirator and the air is drawn through the apparatus very slowly; at the same time the furnace is lighted and the heat gradually increased until all of the cupric oxide has reached a red heat. Maintain this for fifteen minutes, turn off the gas, and continue the aspiration of air until the tube is nearly cold. This preliminary heating is necessary to eliminate any moisture that may be in the tube or in the cupric oxide.

Transfer 0.5 gram of the finely powdered air-dried refuse to a weighed porcelain boat and place it in the combustion tube at the end where the air current enters it. The calcium chloride tube connected with the other end is now accurately weighed, as well as the potash bulbs which follow the **U** tube containing the calcium chloride. All the connections are properly made, the combustion is started slowly, and oxygen is passed through the apparatus. The cupric oxide is brought to a red heat throughout the tube. After completing the combustion (indicated by the absence of black particles in the porcelain boat) the heat is turned off and a slow current of oxygen is passed through until the apparatus is nearly cold. The hydrogen in the refuse is converted into water, which is absorbed by the calcium chloride; the carbon is converted into dioxide, which is absorbed in the potash bulbs. The increase in weight of these tubes is recorded, and the hydrogen and carbon are calculated for an absolutely dry basis. The residue remaining in the porcelain boat represents the true ash.

d. Calorific Value (British Thermal Units per pound).—Detailed descriptions of methods of determining the British Thermal Units and the apparatus used are to be found in many reference books on chemistry and chemical engineering. The following short description largely follows Stillman's "Engineering Chemistry." Various calorimeters are in use, such as Mahler's, Parr's and Thompson's. For rapidity and accuracy, the Mahler's bomb, consisting of a porcelain-lined steel cylinder, is recommended. The calorimeter surrounding the bomb is of thin brass and contains about 2.5 kilos of water. The large amount of water practically eliminates all error due to evaporation. Before this instrument can be used for determining the calorific power, it is necessary to find the water equivalent of the bomb and its appendages.

About two grams of the finely powdered refuse to be tested (powdered so as to pass through a sieve having 10,000 meshes to the square inch) are carefully weighed, and placed in the pan, which is attached to the cap of the bomb. The iron ignition wire is attached in such a manner as to insure proper ignition. The cap is screwed into place and oxygen permitted to flow into the bomb. When the pressure is about 25 atmospheres, the stop-cock is closed and the shell placed in the calorimeter which has been previously partly filled with about 2400 grams of water. The thermometer and agitator are adjusted, and the whole is well stirred, to obtain a uniform temperature. The temperature is then observed from minute to minute for 4 or 5 minutes, so as to determine its rate of change. The charge is then ignited and immediate combustion takes place in the bomb. The temperature is observed each minute until it begins to fall regularly, and then each minute for 5 minutes in order to ascertain the rate of cooling. The agitator should be kept going constantly during the whole period of observation. The shell is now removed from the water, the gas permitted to escape, and the shell itself is opened. The shell should be rinsed out with distilled water to collect the acid formed during combustion. The calorific value of the weighed refuse is then calculated as follows:

Let Q = Calorific value of the weighed refuse,
T = Observed difference in temperature,
a = Correction for cooling,
P = Weight of water taken in the calorimeter,
P' = Water equivalent of shell and appendages,
p = Weight of nitric acid formed,
p' = Weight of iron wire helix,
0.23 calorie = heat of formation of one gram of nitric acid,
1.6 calories = heat of combustion of one gram of iron.

Then $Q = (Ta)\ (PP') - (0.23p\ 1.6p')$.

The calorific value, expressed as calories in this determination, is changed into British thermal units by multiplying by 3.968.

When garbage is reduced for the recovery of grease and tankage, analyses are required in order to indicate the content of phosphoric acid, ammonia, potash, and grease. The following methods of analysis are taken largely from Bulletin 107, Revised, of the Department of Agriculture, Bureau of Chemistry. Similar methods are described in the reports of the Committee on Fats and Greases of the American Chemical Society.

e. Phosphoric Acid.—Dissolve two grams of the air-dried sample in 30 cc. of concentrated nitric acid and a small quantity of hydrochloric acid, and boil until the organic matter is destroyed. After solution, cool, dilute to 200 or 250 cc., mix and pour on a dry filter. Take an aliquot portion of the solution prepared above, corresponding to 0.25 gram, 0.50 gram, or 1 gram, neutralize with ammonium hydroxide, and clear with a few drops of nitric acid. Add about 15 grams of dry ammonium nitrate or a

solution containing that amount. To the hot solution add 50 cc. of molybdate solution (see Bulletin 107) for every decigram of phosphoric acid (P_2O_5) that is present. Digest at about 65 degrees C. for an hour, filter and wash with cold water, or preferably with ammonium nitrate solution. Test the filtrate for phosphoric acid by renewed digestion and addition of more molybdate solution. Dissolve the precipitate on the filter with ammonium hydroxide and hot water, and wash into beaker to a bulk of not more than 100 cc. Nearly neutralize with hydrochloric acid, and cool and add magnesia from a burette; add slowly (about a drop per second), stirring vigorously. After fifteen minutes, add 12 cc. of ammonium hydroxide solution, specific gravity—.90. Let this stand for some time, two hours is usually enough, filter; wash with 2.5% ammonia until practically free from chlorides. ignite to whiteness, or to a grayish white, and weigh. Calculate the $Mg2P_2O_7$ precipitate to per cent. P_2O_5.

f. Ammonia.—Place from 0.7 to 3.5 grams of the substance to be analyzed, according to its proportion of nitrogen, in a digestion flask with approximately 0.7 gram of mercuric oxide, or its equivalent in metallic mercury, and from 20 to 30 cc. of concentrated sulphuric acid. Digest until the mixture is colorless or nearly so, or until oxidation is complete (with some materials, as leather, cheese, milk products, etc., it is necessary to digest for several hours). Remove the flask from the flame, and, while still hot, drop potassium permanganate in carefully, in small quantities at a time, until, after shaking, the liquid remains a green or purple color. After cooling, dilute with about 200 cc. of water, add a few pieces of granulated zinc or pumice stone, in order to keep the contents of the flask from bumping, and 25 cc. of potassium sulphide solution (40 grams of commercial potassium sulphide in one liter of water.) Next add 50 cc. of soda solution (saturated solution of sodium hydroxide free from nitrates), or sufficient to make the reaction strongly alkaline. Connect the flask with the condenser and distill until all ammonia has passed into the standard sulphuric acid in the receiving flask. The first 150 cc. of the distillate will generally contain all the ammonia. The distillate is then titrated with standard alkali. One cubic centimeter of H_2SO_4 $N/2 = 0.0085$ gm. NH_3.

g. Potash.—Saturate 10 grams of the dried material with strong sulphuric acid, and ignite in a muffler at a low red heat to destroy organic matter. Add a little strong hydrochloric acid, warm slightly in order to loosen the mass from the side, and dilute to 500 cc. with water. Evaporate 50 cc. of the solution nearly to dryness, add 1 cc. of dilute sulphuric acid (1 to 1), evaporate to dryness, and ignite to whiteness with full red heat. Dissolve the residue in hot water, using at least 20 cc. for each decigram of potassium oxide, add a few drops of hydrochloric acid and an excess of platinum solution (for the preparation of the platinum solution consult Bulletin 107). Evaporate in a water bath to a thick paste and treat the residue with 80% alcohol, sp. gr. 0.8645, avoiding the absorption of ammonia. Wash the precipitate thoroughly with 80% alcohol, both by decantation and on the filter, continuing the washing after the filtrate is colorless. Wash finally with 10 cc. of the ammonia chloride solution (see Bulletin 107 for its preparation) five or six times. Wash again thoroughly with 80% alcohol, and dry the precipitate for 30 minutes at 100 degrees Centigrade. Weigh as $K_2Pt_2Cl_6$ and calculate to per cent. K_2O.

h. Grease or Crude Fat.—Extract about 2 grams of the air-dried material with several small portions of boiling anhydrous alcohol-free ether, rubbing the sides and bottom of the dish to insure complete solution of the fat. Filter the ether solution through a 5-centimeter filter paper into a small Soxhlet flask. Evaporate the ether slowly, dry the fatty extract for half an hour at 100 degrees Centigrade, put the flask into a desiccator, cool, and weigh.

Further data referring to chemical analyses may be found in Chapters XIV, XV, and XVI.

H.—EUROPEAN AND OTHER FOREIGN DATA

Refuse collection and disposal has been developed with success in England and Germany, and American engineers, within the last 20 years, have given their plants much study. As a proper appreciation of this foreign work requires an understanding of the quantities and character of the refuse material produced, sufficient data have been tabulated to indicate the unit quantities and the composition of some European refuse, based on several trips of investigation made by the authors through England, France, and Germany.

It is the common practice in Europe to place house refuse of all kinds in the same can and to collect it in the same wagon, so that it is dealt with as mixed refuse. In appearance it is dry, frequently even dusty, and has a musty odor. It is not as objectionable a material as garbage generally is in America. The people in those countries are less wasteful than people in America, and the quantities of refuse produced per capita are materially smaller.

A few years ago the only prominent exceptions to the common practice were found in Vienna, and in Charlottenburg, adjoining Berlin. A report of an investigation of refuse disposal, made for Charlottenburg in 1908 by Dr. Thiesing, includes records of refuse materials collected separately, somewhat in accordance with American practice, as follows: In ashes, without sweepings, the following percentages, by weight, were found: Phosphoric acid, 0.27 to 0.36; potassium, 0.38 to 0.55; calcium, 16.24 to 14.25. The following percentages, by weight, were found in garbage: Crude protein, 3.75 to 4.87; fat, 2.31 to 3.98; digestible crude protein, 2.89 to 4.12; pure albumen, 3.42 to 4.64; carbohydrates, 10.78 to 5.83; crude fiber, 1.28 to 3.22; ash, 4.81 to 7.60; and water, 77.07 to 74.50.

Other European statistics of refuse quantities are given in Tables 39 to 48.

The chemical composition of refuse in England and Germany also differs from that in American cities. No analyses of European garbage are available to show the content of grease and tankage, except those made for Charlottenburg, but several analyses have been made to show the calorific value of refuse.

Table 39.—Weight of Mixed Refuse in Some European Cities

City	Year	Population	Average Weight, in Pounds	
			Per cubic foot	Per capita per annum
London	1905	4,100,000	44.0	560
Paris	1895	2,500,000	....	513
Berlin	1907	2,100,000	36.9	315
	1888	1,677,135		
Hamburg	1905	900,000	34.1	390
Sheffield	1908	463,000	55.0	573
Cologne	1905	390,000	....	295
Edinburgh	1908	350,500	27.5	300
Frankfort	1910	350,000	....	215
Newcastle	1907	264,500	....	260
Charlottenburg	1907–08	256,200	....	381
Zurich	1910	180,000	17.2	260
Croydon	1913	170,450	....	484
Barmen	1910	140,000	15.4	270
Wiesbaden	1910	100,000*	....	365
Ealing	1902	65,000	....	465
Chiswick	1913	40,000	....	496
Watford	1908	40,000	....	372
Greenock	1913	16,500	....	402
Average of 14 American cities				860
Average of 8 English cities				450
Average of 77 German cities				319

* Large floating population

Mr. Young, of Glasgow, states that although in London the "fairly combustible matter" in the refuse is 64%, in Edinburgh it is 26%.

The chemical analyses of refuse from Kings Norton, near Birmingham, England, are given in the published specifications, as follows:

Element, etc.	Percentage, by weight
Carbon	36.80
Hydrogen	0.29
Nitrogen	0.29
Sulphur	0.19
Oxygen	7.30
Ash	41.70
Moisture	12.12
	98.69

TABLE 40.—A.—PHYSICAL ANALYSES OF LONDON REFUSE, IN PERCENTAGES.

(From "Disposal of Towns' Refuse," by Goodrich (p. 204), 1901)

	Authority	
	Dr. J. Russell, 1888	G. Weston, 1886 (Paddington)
Coal	0.84	0.15
Breeze, cinder	63.69	28.80
Fine ash	19.51	52.60
Garbage, vegetable and animal matter	4.61	14.20
Paper	4.28	......
Rags, clothing, bagging, etc	0.39	0.43
Bottles	0.96	0.30
Metals	0.21	0.37
Tins	0.79	......
Bones	0.48	0.25
Glass	0.47	......
Crockery	0.55	2.90
Straw, fiber, etc	3.22	......
	100.00	100.00

B.—CHEMICAL AND OTHER ANALYSES OF WINTER REFUSE FROM KINGS NORTON, NEAR BIRMINGHAM, ENGLAND. (LEASK)

Carbon	36.80
Hydrogen	0.29
Oxygen	7.30
Nitrogen	0.29
Sulphur	0.19
Moisture	12.12
Ash	41.70
	98.69

THEORETICAL CALORIFIC VALUE B.t.u.

Winter	4500
Spring	4300
Summer	3000

COMPOSITION OF REFUSE

	Yearly %	Sept. %
Garbage	39.5	49.37
Coal and fine dust	45.4	38.80
Rubbish	9.3	7.73
Glass, metals, etc.	5.2	4.28

One ton of 2240 lb. measured 3.75 cu. yd.

Paris, which has been very conservative, and has not made much progress in refuse disposal in the last 20 years, collected in 1895, as an average, 415 liters or 233 kg. (514 lb.) per annum, or 1.137 liters or 0.639 kg. (1.40 lb.) per day per inhabitant. The composition is reported to be about the same as in other cities, but no analysis is

given. Tests have shown the calorific value of Paris refuse to be about 4500 B.t.u. The privileges of the trained rag pickers, who search, not only the street surfaces, but also the house cans, which they dump temporarily on a cloth for the purpose of looking for articles which can be cleaned and sold by them, would cause analyses probably to be somewhat different from those in other cities.

Table 41.—Refuse Incinerated in Plymouth, England

(From a paper entitled "The Collection and Disposal of House Refuse in Plymouth," by James Paton, Borough Engineer and Surveyor)

Description of refuse received at the Destructor Works from April 1, 1908, to March 31, 1909:

	Percentages
Ashes and clinkers	66.74
Bones	0.08
Bottles	0.12
Condemned meat and animals' carcasses	0.45
Broken glass and crockery	2.66
Fish offal	1.52
Mattresses and bedding	0.07
Old iron and steel	0.08
Paper	12.84
Rags	0.13
Straw	0.54
Tins	0.53
Vegetable refuse	9.44
Bagging	0.02
Garden refuse	4.78
Total	100.00

The following dead animals were also destroyed:

Dogs, 199; cats, 331; bullocks, 106¼; pigs, 31; sheep, 69; rabbits, 81; fowls, 4; calves, 6; lamb, 1; monkey, 1; deer, 1; goat, 1. Total, 831¼.

An approximate average figure for the quantity of mixed refuse produced per capita in German cities is stated to be 1 lb. per day, as compared with 2 to 3 lb. per day in American cities. The difference is important when comparisons are made between European and American practice, in both refuse collection and disposal.

Fig. 9 is an analysis of the refuse of Copenhagen as given by de Fodor.

Combined refuse in England contains more unburned coal and more waste organic matter than in Germany. The products of com-

bustion—clinker and ashes — in England are only one-third of the weight, in Germany one-half, and in America about one-fourth. In America, therefore, possibly three-fourths may be burned.

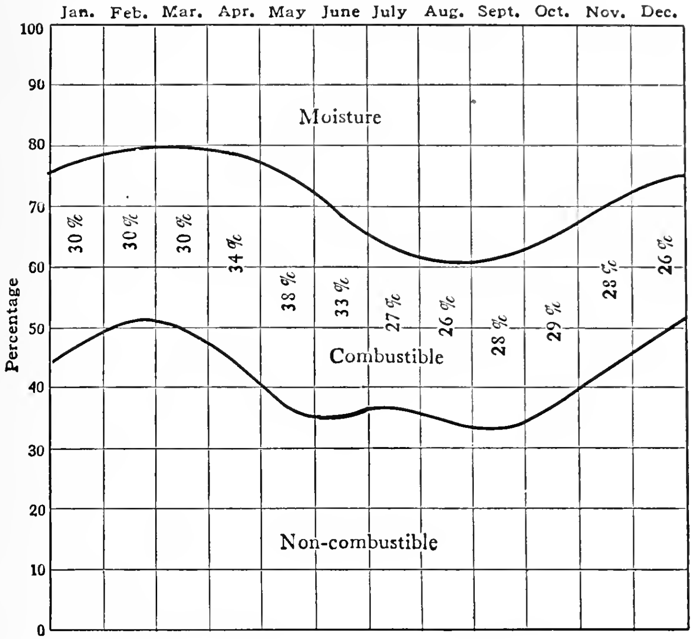

FIG. 9.—Analysis of Copenhagen Mixed Refuse.

According to Petermann (Gembloux) and Richard (Brussels), household waste from various sources, from which 13% of water had previously been removed by drying, contains by weight:

Organic matter:	
Nitrogen	0.392%
Carbon, hydrogen, and oxygen	26.608%
	27.000%
Mineral matter:	
Phosphoric acid	0.426%
Potassium	0.074%
Sand	67.000%
Salts of iron, lime, aluminum, etc.	5.500%
	73.000%
Total	100.000%

TABLE 42.—COMPONENT PARTS OF REFUSE OF SHANGHAI, CHINA, FOR EACH MONTH

(From "Modern Destructor Practice," by W. F. Goodrich, p. 180)

Component parts	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Cinders and ashes	27.39	31.26	30.53	27.54	17.17	21.70	12.84	12.22	11.30	10.21	9.97	8.33
Fine dust	45.29	40.79	42.41	40.80	37.20	43.79	47.63	35.59	31.79	34.51	35.05	32.79
Vegetable, animal and various organic matter	13.78	14.75	14.30	17.55	34.12	18.09	23.79	37.75	45.93	44.01	45.55	50.10
Waste paper	0.55	0.56	0.39	0.42	0.44	0.57	0.33	0.22	0.20	0.24	0.18	0.21
Straw and fibrous material	8.10	8.69	9.25	9.67	8.09	11.82	11.97	9.38	7.28	7.10	6.75	5.92
Tins	0.54	0.43	0.29	0.26	0.26	0.28	0.23	0.22	0.12	0.24	0.18	0.22
Crockery	0.39	0.46	0.49	0.37	0.28	0.37	0.28	0.25	0.18	0.25	0.22	0.28
Bones	0.06	0.06	0.05	0.07	0.09	0.09	0.06	0.06	0.05	0.06	0.6	0.07
Broken glass	0.08	0.09	0.08	0.08	0.07	0.10	0.12	0.12	0.08	0.10	0.09	0.07
Rags	0.18	0.14	0.12	0.17	0.16	0.22	0.23	0.18	0.17	0.18	0.18	0.20
Iron	0.06	0.06	0.05	0.06	0.05	0.08	0.08	0.09	0.05	0.06	0.08	0.08
Wood	0.15	0.12	0.11	0.15	0.13	0.18	0.19	0.23	0.17	0.19	0.22	0.26
Bricks and broken roof tiles	3.50	2.59	1.93	2.68	1.96	2.70	2.26	1.70	2.68	2.86	1.48	1.49
	100	100	100	100	100	100	100	100	100	100	100	100

TABLE 43.—WEIGHT OF REFUSE IN NEW YORK, LONDON, AND BERLIN, EXCLUDING STREET SWEEPINGS

(In pounds per capita per annum)

Kind of refuse	New York. Commission (1907)	London. Weston (1888)	Berlin. Bohm & Grohn (1898)
Garbage	181	78	100
Ashes	936	454	171
Rubbish	93	28	44
Totals	1210	560	315

TABLE 44.—ANALYSES OF BERLIN MIXED HOUSE REFUSE WHICH DID NOT BURN WITHOUT ADDED FUEL (BOHM AND GROHN).

PERCENTAGES BY WEIGHT

A.—PHYSICAL ANALYSES, 1895

Components	March and April	July and August	Averages
Coal	0.13	0.21	0.17
Cinders (partly burned coal)	1.20	1.32	1.26
Siftings (mainly ashes)	57.12	43.19	50.16
Clinkers	1.58	1.18	1.38
Paper	2.54	5.97	4.26
Rags	0.74	1.57	1.15
Bones	0.51	0.55	0.53
Wood	0.14	0.66	0.40
Sundry vegetable and animal matter	29.02	36.07	32.54
White glass	0.46	0.51	0.48
Colored glass	0.69	0.89	0.79
Stoneware	5.01	7.19	6.10
Iron	0.19	0.20	0.20
Tin cans and other metals	0.67	0.49	0.58
	100.00	100.00	100.00

B.—CHEMICAL ANALYSES, APRIL, 1895

Description of material	Hygroscopic water	Combined water and CO_2	Combustible organic matter	Incombustible and fixed matter
Original material	17.62	5.54	11.94	54.90
Siftings, 57%	10.91	2.54	13.27	73.28
Coarse material, 43%	26.55	9.53	10.20	53. 72

Table 45.—Monthly Production of Refuse at Charlottenburg, Germany

(Data from Report by Professor Dr. Thiesing, Berlin, 1908)
The population of Charlottenburg in 1908 was 256,200

Year	Month	Average Quantity, in Tons per Day			
		Garbage	Ashes and sweepings from houses	Rubbish	Total
1907	May	30	97	26	153
	June	28	78	17	123
	July	22	72	21	115
	August	22	78	20	120
	September	30	88	30	144
	October	32	93	39	164
	November	27	111	28	166
	December	24	138	32	194
1908	January	23	142	28	193
	February	18	132	29	179
	March	23	125	33	189
	April	24	121	38	183
Annual averages		25	106	28	159
Percentages		16	67	17	100
Pounds per capita per year		61	254	64	379

On the other hand, the following results were obtained for the garbage as delivered at the municipal unloading station in Brussels, (by weight on dry basis):

Organic matter:	
Nitrogen	0.409%
Carbon, hydrogen, and oxygen	23.471%
	23.880%
Mineral matter:	
Phosphoric acid	0.628%
Potassium	0.322%
Sand	66.887%
Salts of iron, lime, aluminum, etc.	8.283%
	76.120%
Total	100.000%

Table 46.—Analyses of Refuse in Barmen, Germany, Reduced to Dry Material and Expressed in Percentages by Weight

Dates	Mar. 26, 1908	July 10, 1908	Oct. 23, 1908	Jan. 25, 1909	Mar. 2, 1909	Sept. 9, 1909	Dec. 28, 1909	June 11, 1910
Fine ash	46.00	37.73	16.00	35.36	37.90	35.17	40.14	23.15
Clinker	21.06	5.90	12.90	23.65	26.75	16.72	20.73	12.10
Glass	4.42	15.90	7.70	5.26	2.53	2.47	2.57	5.46
Iron	1.26	3.30	3.40	1.08	1.19	1.84	1.41	1.92
Bones	0.45	1.86	1.98	0.74	0.74	1.41	0.54	1.06
Eggshells	0.14	0.21	0.36	0.09	0.77	0.19	0.09	0.43
Vegetable matter	2.18	17.24	26.40	3.09	4.39	20.13	6.35	26.10
Unsorted matter	0.20	0.37	0.90	0.59	0.39	0.18	0.48	0.04
Coal and cinders	22.40	11.35	21.40	29.04	24.05	19.05	26.02	11.96
Wood	0.36	1.54	2.50	0.23	0.30	0.39	0.41	0.80
Paper	0.34	2.61	4.70	0.76	0.31	1.65	0.47	3.05
Straw	0.13	0.25	0.53	0.17	0.02	0.09	0.13	0.06
Rags	0.87	1.29	1.60	0.32	0.47	0.56	0.45	0.45
Leather	.....	0.37	.....	0.03	0.01	0.01	0.02	.....
Feathers	.....	0.01	0.05	0.02	0.01	0.01	0.05	0.06
Miscellaneous	0.15	0.07	0.15	0.07	0.15	0.13	0.15	0.02
Percentage of moisture in the above materials	14	not determined	34	16	18	29	21	32

Note.—The material was incinerated without the addition of fuel. One kilogram of fuel produced from 0.8 to 1.5 kg. of steam superheated from 260° to 330° Centigrade (500° to 626° Fahr.).

TABLE 47.—PROXIMATE CALORIFIC VALUE OF HOUSE REFUSE IN CITIES OF CENTRAL EUROPE.

City	British thermal units per pound of refuse	Reference
Barmen	4050	*Zeitschrift*, Oester. Ing. und Arch.-Verein, No. 35, 1906, p. 497
Beuthen, Silesia	8050	
Dortmund	4140	
Frankfurt, a/M	4086	
Miskolcz, Hungary	2880	
Vienna (Florisdorf), winter	2943	
Vienna (Guerecki), winter	2876	
Wiesbaden	4140	
Berlin, summer refuse	1890	*Elektrotechnische Zeit.*, Heft 26, 1907, p. 643
Charlottenburg, summer	1980	
Charlottenburg, winter	1800	
Mainz	3780	
Berlin, winter refuse	1314	*Gesundheits Ing.*, No. 42, 1908, p. 664
Hamburg	2556	Calculated from local data
Hanover	2198	
Kiel	3240	*Die Städt.* Verbrennungsanstalt, L. Boto, 1907, p. 8
Pforzheim	3600	*Zeit. Ing.*, No. 40, 1907, p. 665

TABLE 48.—CALORIFIC VALUES OF CERTAIN REFUSE COMPONENTS

Components	ENGLISH REFUSE (Dawson)		GERMAN REFUSE (Leask) B.t.u.
	Artificially dried B.t.u.	With natural moisture B.t.u.	
Coal	14,000	9334	9380
Coke	12,000	8000	
Breeze and cinder	6,000	4000	....
Offal and bones	8,000	5334	....
Bones	....	....	540
Rags	5,000	3334	3600
Hair	....	....	1620
Paper	3,800	2534	3950
Straw			5400
Vegetable refuse			2165
Wood	....	....	6280
Sawdust	....	....	5750

According to Mr. G. Weston, the refuse of London-Paddington had the following composition:

Ashes	52.6%
Cinders	28.8%
Animal and vegetable wastes	14 2%
Broken stoneware	2.9%
Coal	0.15%
Bones	0.25%
Rags	0.425%
Old iron	0.35%
Other metals	0.025%
White glass	0.075%
Colored glass	0.225%
	100.000%

According to Mr. Henry Whiley, in Manchester, where at the time the pail system of dry closets was used for the collection of excreta, this refuse had the following composition:

Ashes and excreta mixed with ashes	64.50%
Dust and cinders	34.55%
Fish waste and bones	0.15%
Dead animals	0.05%
Shoes, rags, paper, etc.	0.05%
Vegetable matter	0.05%
Glass, pottery, and bricks	0.60%
Old metal	0.05%
	100.00%

Table 42 shows the component parts of the refuse of Shanghai, China, for each month, as contained in a report of the Shanghai Municipal Council for 1899.*

The following is a percentage analysis of the refuse of Melbourne, Victoria, as given by Goodrich.†

Screenings, sand, or fine dust	42.81
Cinders, coke	26.55
Clinker, stones, etc	1.32
Vegetable matter	13.28
Paper	7.36
Rags	1.68
Straw or fiber	1.63
Broken glass and bottles	1.44
Crockery	0.56
Bones	1.03
Iron	0.33
Old tins	1.11
Wood	0.90
	100.00

* "Modern Destructor Practice," p. 180. † "Modern Destructor Practice," p. 165.

I.—SUMMARY

The foregoing data and discussions emphasize the marked variation in the quantities, proportions, and characteristics of refuse materials in different cities and towns, and even in different districts of the same city. Also, in each city, the per capita production of refuse varies from year to year. The effects of the weather, season, and climate are always quite appreciable.

These many factors make it difficult to estimate with exactness the quantities and characteristics of the refuse to be expected in a city, unless a careful study of all the pertaining local conditions is previously made. Such studies, properly conducted in advance of a recommendation for new works, will result in obtaining a more effective and economical plan for refuse disposal than without them, and one which is better adapted to the city in question.

Of great assistance in this regard are the published special reports and the records of city officials. To make them more readily comparable and useful in different communities, they should in the future be tabulated on standard forms. A satisfactory form, which can be recommended for use, has been published by the American Public Health Association, and also adopted by the American Society for Municipal Improvements, and is reproduced on pages 231–235.

As local usage has sometimes given to the same material different names in different places, we have felt obliged, for use in the present work, to select definite terms for each of the materials and to classify them for convenient discussion. We have given their quantities, composition, and unit weights, so far as available and necessary to represent different parts of our country and also of some foreign countries, in order to indicate, as far as practicable, the separate effects on the refuse from a variety of causes.

It is hoped that in the future municipal refuse will be more frequently measured and analyzed, because a knowledge of its quantities and compositions is essential to determine the best means of collection and disposal.

CHAPTER II

HOUSE TREATMENT

The problem of a proper disposal of refuse starts at the point of its origin. In the case of garbage, this is the house or market; in the case of trade refuse, it is the manufacturing establishment which produces it; in the case of manure, it is the stable or the street surface.

The term "house treatment" of refuse, as used herein, refers to the handling of the materials, originally in the house, stable, or factory, previous to the time when they are taken up by the collector to be placed in the collection wagon.

The house treatment is of greater importance in the general problem than is commonly considered. From the point of view of the public, official house refuse originates after the garbage, ashes, and rubbish have been removed from the kitchen, furnace, stove, or waste basket, and placed in a receptacle, either in the cellar, or in the yard adjacent to the back door, or on the sidewalk. Further, there is no part of the refuse problem which affects the general aspect of a city's streets, alleys, and yards more than the house treatment, because failure to keep the refuse in proper receptacles quickly produces on the streets unsightly and objectionable conditions. The chief requirements for efficient house treatment are simplicity and cleanliness.

Much good can be done by the collection department in educating the people as to the results of carelessness. In nearly all cities, therefore, some sort of education is attempted along this line, as, for instance, by distributing cards setting forth rules and regulations affecting the size, make, and location of cans, and how to use them. In many instances, such work of the department is defeated if carelessness and slovenliness are permitted in the back yard and alley adjoining the house, thus creating nuisances that affect directly more people than any other objectionable conditions, even at isolated points of disposal. Careful attention to house treatment may also reduce materially the cost of the collection service.

The factors influencing these conditions are discussed as follows:

A.—DEGREE OF SEPARATION

The first factor controlling the house treatment is the method of disposal which is best suited to the locality. If the garbage is to be fed to hogs or treated at a reduction plant, it is necessary that it be well separated from all other kinds of refuse. If the ashes are to be utilized to fill up low land, it is advisable, though not always necessary, to separate from them all garbage, and sometimes, also, the rubbish. Such requirements would demand a three-part separation at the house; in other words, the house treatment would require three separate cans or receptacles, or two receptacles if the rubbish is bundled. In some cities the garbage and rubbish are combined and disposed of by incineration. Then, also, two cans will suffice—one for garbage and rubbish and the other for ashes. In still other cities, one can contains only garbage, and the rubbish and ashes are mixed. Where all refuse is mixed to be burned in incinerators, only one can or receptacle is required.

The latter is the common practice in Europe. In the larger cities of America, the one-can system is the exception rather than the rule. In Seattle, the Borough of Richmond of New York City, Savannah, Atlanta, Montgomery, San Francisco, and in some other places, mixed refuse is placed by the householder in one receptacle. Where garbage is collected alone, sometimes an order is issued by the collection department requiring that it be drained and wrapped in waste paper before it is placed in the can, as in Minneapolis, and Trenton. This practice has apparently been satisfactory. Dr. P. M. Hall, Health Officer in Minneapolis, has stated its advantages as follows:

"The first step in the disposal of garbage is carrying it from the house and placing it in the can, and the question naturally arises, why should not this step be a sanitary one and be made in the direction of educating the householder? Under existing conditions in almost every city, the can is as great a nuisance as the garbage itself, if not greater. In the primitive days, the Indian, when the offense from the waste products of his housekeeping became too noisome, moved away, but in our day and generation, we remove the garbage and keep the smell. Take the first step—the placing of the garbage, the waste food, or droppings from our tables, in any kind of receptacle—wood, galvanized iron, or what-not, and with the presence of heat, moisture, and flies, you will very soon have a foul, maggoty, fly-breeding mess of putrefaction. Such a mess is necessarily a nuisance, requires frequent removal, and is a nuisance every time it is handled, from the can to final disposal Is it necessary that this condition of things should be? Is there no way to eliminate these breeders of putrefaction, heat, moisture, and the fly? Is it not a little bit inconsistent that we legislate and talk about fly-infection, when we are perpetuating the fly nuisance in the garbage can by furnishing a most pro-

lific breeding place? It has been said that the annoyance of the can probably never will be done away with. It seems that this condition of things has been accepted everywhere and that nobody has tried. We find, however, exceptions in two cities—one in the United States and the other in Canada—where at least an effort has been made to keep the garbage can from being a constant nuisance, and that is what I have come to tell you about—how these two cities have been trying—and, I will say, with a great measure of success—to make the garbage can no longer a nuisance.

" 'Drain garbage of all moisture, then wrap it in paper before putting it in the can, and it will neither smell bad in hot weather, nor freeze and stick to the can in cold weather. Do this and have a clean can at all times.'

"Heat, moisture, and the fly are all eliminated. This rule was put into practice in Minneapolis in February, 1907, and is still in force. The campaign of education was a hard one, but we have won."

When garbage is fed to hogs, and even when it is taken to reduction works, some collectors have refused to take away the paper, and have returned it to the can. A local decision, regulating this matter, should be made for each municipality.

It is important, in the case of infectious diseases, to keep out of the general collection all refuse from sick rooms. This material should be disposed of separately and in a proper way, according to regulations.

At West New Brighton and at Montreal where mixed refuse is collected and burned, it has been found expedient to keep out some of the ashes, in order to reduce the bulk of the material to be burned.

The most common house treatment in American cities is the two-can system, in which the garbage is kept in one receptacle and the ashes and rubbish in another. This is the case in the larger cities of the northeastern part of the United States, where feeding and reduction methods are in most common use.

In Europe the one-can system is the most common. In Paris galvanized-iron pails containing the refuse stand ordinarily in the yard. The pails are furnished by the householder. In the morning, about 5 o'clock in summer or 6 o'clock in winter, the janitor places them on the sidewalk in front of the premises. Before 8 o'clock they are collected by the city. In Zurich and in some cities in Germany the same custom prevails, but the pails are generally furnished by the municipality.

The degree of separation should be determined specially in each city, to suit the most economical method, both of collection and final disposal, and also to suit the convenience of the householders.

B.—RECEPTACLES

1. Type.—Not many years ago, in American cities, large wooden bins, infrequently emptied, were used for the reception and storage of all kinds of refuse. They were generally placed in the alley, and were often overfilled, allowing the contents to spill and form unsightly refuse heaps. Later, wooden pails or boxes were used for the garbage; these were removed more frequently, but the ashes and rubbish were put into the wooden bins or scattered in loose piles in the alley. Sometimes concrete refuse boxes are advantageously used, as, for instance, in St. Louis.

The next improvement was the introduction of the metallic can with cover. Various sizes and shapes of such cans for garbage, ashes, and rubbish have been devised. Some have close-fitting covers which are opened by a lever, operated by pressure with the foot, and close automatically. Others are cylindrical, or are larger at the top than at the bottom, and are fitted with covers.

In cold climates metal receptacles are not advantageous in winter, and wooden pails are preferable. The reverse is the case in hot climates.

It is essential to have a tight-fitting cover, in order to keep small animals away from the garbage, to keep dust from blowing away from ashes, and to keep rain out of the refuse. A tight cover will also prevent room sweepings from being blown about. As the latter may contain disease germs, it would be dangerous to have them scattered around. Most kinds of refuse attract flies, and afford opportunities for them to breed. Uncovered garbage cans attract rats, cats, and dogs, thus increasing the chance of such cans being tipped over and their contents spilled.

The best size for the can is partly determined by the number of men attending each collection wagon. Ordinarily, the can should not be larger than one man can easily lift and empty into the wagon. The usual capacities range from $\frac{3}{4}$ to 4 cu. ft., a reasonable size for a garbage, rubbish, or ash can. If it holds only garbage from one family, with frequent collection, $\frac{3}{4}$ cu. ft. is sufficient. Garbage cans with a wider top are particularly suitable in cold climates, because they will not so easily become clogged by ice. The top, however, should be only slightly larger than the bottom, in order that they may not be top-heavy and tip over. Cans for rubbish alone may be 4 cu. ft. in capacity.

Two styles of cans are here shown: One can (Figs. 10 and 11) is partly underground (Rochester Can Co.). An outer shell of heavy galvanized iron is placed permanently underground. Inside is the

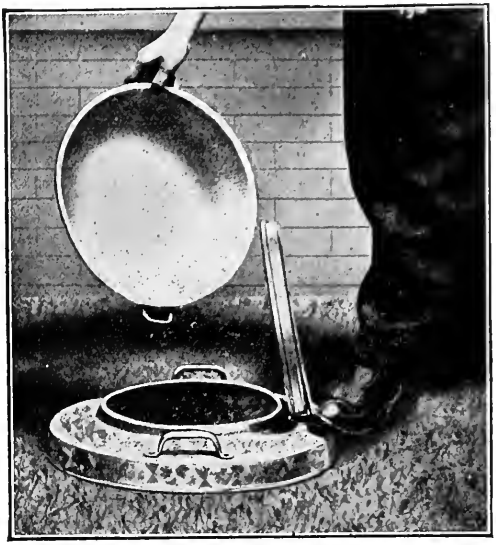

Fig. 10.—Underground Garbage Can.

garbage container, having a capacity of from 10 to 15 gal. The whole is closed with a heavy tight-fitting, hinged cover, and this is lifted by the collector. To deposit the garbage, a hinged lid in the cover is lifted by pressing the foot on the trip.

The other can (Fig. 12) stands on the surface of the ground. The handle, when pressed down, locks the lid securely (the Schaffer can).

For the reception of ashes it is well to have a can made of extra heavy galvanized sheet-iron well reinforced with iron bands at top and bottom, and heavy steel slats riveted to the body and through the top and bottom bands. Fig. 13 shows such a can, made by the Rochester Can Company.

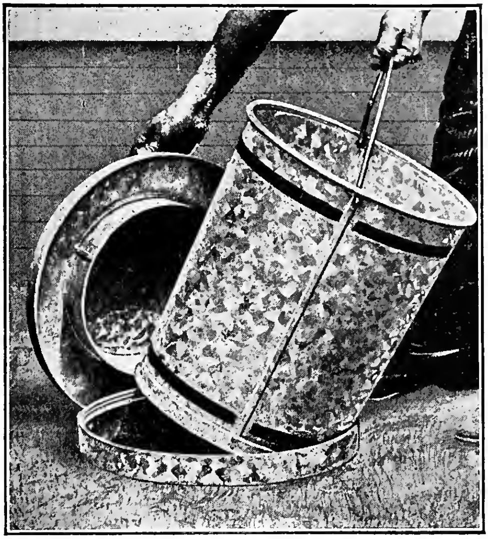

Fig. 11.—Removing the Container of the Underground Garbage Can.

For rubbish, a metallic can is not necessary; therefore, in Cleveland, and in other cities, canvas or burlap bags are used. In some cities, rubbish is tied in bundles ready for the collector.

All refuse receptacles have to stand hard service, and should be strong, with corrugated or rein-

Fig. 12.—Garbage Can, with Locking Cover.

forced sides. The size depends on the quantity of material to be handled and the interval between collections, but the filled receptacle should always be small enough to be handled easily. For ashes, when they are collected infrequently, a large receptacle must be used, but it may then be taken to the wagon on a small roller truck which the collector carries with him.

2. Location.—The location of the house refuse receptacle materially influences the cost of the collection service. Where there are alleys, it is a common practice to place the can near the back door of the house. Where there are no alleys, as in most parts of New York City and in most European cities, the householder is required to place the can in the street at the curb or house line. In many European cities, the householder places the can at

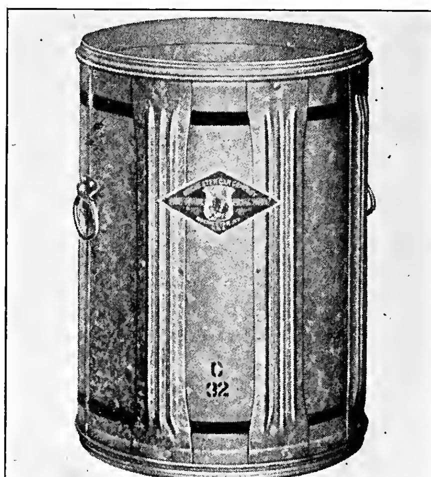

Fig. 13.—Can for Ashes and Rubbish.

his front doorstep late in the evening, and it is emptied during the night or early in the morning. We have found, in America, that where this method is followed, the cans are sometimes damaged, tipped over, or stolen.

One of the difficult features of garbage collection in America is to

fix a place where the can may be found readily by the collector. Frequently they are kept in odd, out-of-the-way corners, so that, especially when the collector is working at night or is a new man, he cannot find them readily. The back yard near the kitchen door is the preferable location for the can, under our average conditions. The alley is not the best place for it, because it is too easy of access by dogs and unlicensed ragpickers, and can be easily upset or damaged by passing vehicles. The cellar is also an improper place for the can, because of the necessity and inconvenience of having the collector enter the house.

The studies relative to the collection service in Milwaukee, made in 1911, indicated that from six to twelve stops can be made by each wagon in one hour. This service was for garbage when disposed of separately, the cans being placed in general near the back door. In London,* one collector, under normal conditions, is said to make twenty-four or twenty-five stops per hour. In districts where the cans are placed at the curb, it is quite possible to make as many as fifty collections in one hour. Lately, bids for the collection of refuse were received in Plainfield, N. J., under two schedules: (*a*) that the householder should set the can out at the curb, and (*b*) that the collector should carry the can out from the basement. The lowest bid under schedule (*b*) was $12.00 per house per year, and under schedule (*a*) it was only $4.62. For a city of 100,000 people, having, say, 20,000 houses, this difference would amount to $147,600 per year. Therefore, it may be cheaper, from the collection point of view, for the householder to place the can at the curb. Nevertheless, the citizens sometimes prefer to pay a higher rate, in order to avoid the burden of setting the can on the sidewalk, and the undesirability of having the refuse exposed in front of the house.

Various other suggestions have been made to provide suitable locations for the can. At some army posts, where both the front and back of the quarters are easily accessible, it has been the practice to build small lattice fences, enclosing a platform on which the cans are placed. In some cities, where the alleys are sufficiently well paved, the cans are placed in boxes which are set into the fence, and open both inward and outward.

The location of the can should be as uniform as possible throughout a city, and so that the collectors can work most expeditiously. To promote the most efficient correlation between the house treatment and the collection service, it may frequently be worth while to employ an inspector to instruct housekeepers.

A device for keeping garbage cans in place has been designed by

* "Cleansing of Cities and Towns," by Arthur May.

Dr. M. E. Connor, General Inspector, Department of Sanitation, I. C. C., Ancon, Canal Zone. The object of this so-called "garbage-can stand" is to make the cans fly- and rat-proof and to furnish a self-closing cover.

3. Cleaning.—The most economical way for a city to keep house cans in good condition would be to compel the house occupants to clean them. However, such cleaning is neglected so frequently that collection departments have found it impossible to rely on it. Keeping the can clean is important, for several reasons: A dirty can is unsightly and odorous; it contains, in the dirt left in the corners, organisms which may cause putrefaction; and, when fresh refuse is placed in an unclean can, it may become quickly seeded with these organisms, with hastened decomposition in hot weather.

Of the various methods to insure clean cans, the one practiced in some cities of America and Europe is quite satisfactory. When the full can is placed on the collecting wagon, a clean one is left in its place by the collector. The cans, after being emptied at the disposal plant are at once thoroughly disinfected or cleaned by washing with a hose and then replaced on the wagons.

This system has many advantages, the most important being that the department has full control as to the type of can and its condition. The householder is as responsible for the safety of the can on his premises as he would be if he owned it. At Kiel, Germany, it required eight persons on the day shift to clean the cans coming from a population of about 170,000.

In Buffalo, when the collection of refuse was done by contract, the contractor was required to sprinkle a disinfectant over the inside of each can at the house after he had emptied it. The collector carried with him, for this purpose, a box of disinfecting powder. This method may be subject to careless treatment, and, without conscientious collectors and rigid inspection, may prove ineffective. At some plants the cans are cleaned with boiling water.

In Lansing, the collector takes the full can and leaves an empty one. Householders are not obliged to wash the cans, but it costs the city $1500 a year to wash and disinfect them. Objectionable substances, such as glass, rubbish, and sweepings, are often put in the garbage cans and are not detected until emptied. The extra handling of the cans in the wagons has caused greater depreciation, and therefore dumping into collection wagons may be preferred.

4. Ownership.—The collection department should designate the proper ownership of the can, so that responsibility for compliance with the rules can be fixed. In most cities, those persons who produce the refuse are supposed to provide the receptacles. This is generally

satisfactory when the owner lives on the premises. Tenants providing proper garbage cans, sometimes finding it difficult to prevent them from becoming lost or stolen, have refused to provide new cans, claiming that it is the duty of the proprietor or city to supply them.

C.—FLIES

In the summer a most important feature of the house treatment relates to fly breeding. Although probably more than 80% of all house flies breed in stable refuse, as discussed in Chapter XIV, the number breeding in garbage is considerable. The garbage delivered to the incinerator at Milwaukee was found to be swarming with fly maggots.

The extent to which flies actually develop from the maggots in the garbage depends on the following facts: It requires about two weeks for the fly to develop after the egg is laid. Therefore, if all the garbage is destroyed within two weeks after it has originated, the contained maggots will be destroyed with it. In uncovered cans, some of the maggots are known to crawl from them into the ground and bury themselves during the period of pupation.

Observations in European cities point to the fact that, for the same number of persons, mixed refuse harbors fewer maggots than garbage alone. If the ashes and rubbish form a sufficiently large part of the whole, so as to produce a dry and dusty refuse, the material will not be suitable for fly breeding. The Minneapolis method of wrapping garbage in paper when separately collected is also effective in preventing the multiplication of flies. The best preventive, however, is cleanliness and a sufficiently frequent collection, to prevent the development of the fly from the egg.

To catch the living fly in or about a house, the best means are commercial Tanglefoot white fly paper inside the house, and light-colored baited conical traps of fine wire netting outside of the house, set in a well-lighted place and out of the wind. The bait should be contained in a shallow, circular pan. For fly paper the best bait is 2 parts of rosin to 1 part of castor oil; for the traps, it is either milk with overripe bananas or 1 part of molasses with 3 parts of water, slightly fermented. The flies are best killed by immersing the trap in hot water.

D.—SPECIAL TREATMENTS

Certain special treatments of the refuse in the house, before it is placed in the can, are also sometimes of value.

1. Screening.—Rotating and fixed screens, to be attached to ash

cans, can be purchased, and are useful in sifting out some of the unburned coal from the ashes. This unburned but scorched coal, called "cinder" in England, amounts to from 15 to 30% of the ashes coming from the average house furnace or stove. Although it is not as combustible as new coal, it has still a good calorific value, and is particularly useful for banking fires at night.

2. Burning at House.—The burning of combustible refuse at the house would be the cheapest method of disposing of it, and would relieve the community of the cost of collection, transportation, and disposal. Mr. Arthur May, Superintendent of the Cleansing Department, Borough of Finsbury, London, considers this procedure as part of a householder's responsibility to the community, and recommends that a by-law be enacted to compel the burning of combustible refuse. However, if done at many houses in a crowded district, a few careless persons might cause a great nuisance, especially if the refuse contained some garbage. In general, the practice, therefore, has not been favored.

Dr. S. H. Durgin, former Health Officer of Boston, has recommended a simple means of carbonizing the garbage in the flue leading from the kitchen stove. The garbage is slowly dried, then charred, and finally can be used as fuel, all without the discharge of any odors. Although this contrivance is quite satisfactory under favorable conditions, it has not been generally used because of the necessity of giving it careful attention and regular charges and removals, depending on the humidity of the garbage and the heat in the flue.

Gas ovens for burning garbage alone are designed like a small stove, to stand in the kitchen and be connected with the chimney. The garbage is consumed by gas flames coming from below. A small family might find such a disposal too expensive to operate, and it also requires careful attention. The operation, including fixed charges, may require from 1000 to 2000 cu. ft. of gas per month. Therefore, only a comparatively small part of the population could afford this expense. Several of such garbage burners are in the market.

A very common method of rubbish disposal for isolated houses and small towns and villages is to burn it in basket cages in the back yards, or, in case of schools or institutions, in a small masonry oven; but care must be taken in starting and continuing the fires, in order to prevent offensive odors. (See Chapter X.)

3. Wrapping.—Wrapping the garbage before placing it in the can, as already described, has advantages, particularly in small residential communities, and when the garbage is to be incinerated. (See also Chapter XVII.) When, however, the garbage is to be fed to hogs, and requires the prior removal of the paper and its separate destruc-

tion by fire, the wrapping method has been strongly objected to at the hog farms. The wrapping has also been strenuously objected to if garbage is taken to reduction works, as the paper absorbs and removes too much grease, and the labor of unwrapping is expensive.

4. Closed System.—In some European cities and in certain districts in New York City, there has been used what is termed the "closed system." The house cans are equipped with special sliding covers, which fit into guides over openings in the top of the collection wagons. Thus the contents of the cans can be discharged into the wagon without exposure to the air.

5. Temporary Cold Storage.—In the Pennsylvania Railroad Stations in New York and Washington, there are cold-storage rooms for the garbage from the respective restaurants, for its sanitary preservation until it can be removed.

E.—IMPROPER CONDITIONS, AND COMPLAINTS

Very little definite information is available regarding this subject. During an investigation of refuse disposal in Louisville (1917) by Greeley, special studies of house treatment were made, and actual conditions were observed in a number of districts of different characteristics. The results are summarized in Table 49. The lack of proper house treatment and the causes of complaints are shown. Only 17% of the houses used garbage cans. In all other cases the garbage was found by the collector in barrels, boxes, dish pans, and miscellaneous receptacles.

At Washington, D. C., there is kept a record of complaints, subdivided according to the class of refuse material. The results of two years are shown in Table 50.

In Toledo, Ohio (population 243,109), during the first five months of 1920, the number of complaints received from the collection service in reference to garbage averaged 12.8 per day, and these were quite well distributed about the city. This was equivalent to 5.26 complaints per 100,000 population per day, as compared with Washington and Milwaukee, where they were 1.10 and 1.53, respectively.

F.—ESSENTIALS OF TREATMENT

A thorough attention to the essentials of the house treatment is necessary for the general success of the work of the collection department.

1. Garbage, Ashes, and Rubbish.—The simplest treatment will generally be preferable. From experience in many cities, it is practicable to maintain a two- or three-can system, but this is not done

TABLE 49.—SUMMARY OF FIELD INVESTIGATIONS OF HOUSE TREATMENT OF REFUSE IN LOUISVILLE, KY., 1917

Items	Character of District													Percentages
	Industrial	Semi-Industrial				Neighborhood district	High-Class Residence			Foreign		Colored		
		a	*b*	*c*	*d*		*a*	*b*	*c*	*a*	*b*	*a*	*b*	
Total number of houses	36	16	25	33	75	137	29	27	29	89	63	83	113	
Vacant houses	....	....	....	2	....	2	6	3	9	....	....	....	....	
Number of houses setting out receptacles at curb	21	16	9	15	25	77	16	15	18	60	46	27	26	
Total number of collections	84	12	16	19	41	78	23	21	26	57	55	36	27	
Frequency of collections:	(1)				(2)									
Once per week	3	3	2	7	14	......	2	3	4	34	20	20	25	43% of collection
Twice per week	2	7	6	6	9	......	4	4	6	25	26	8	1	33% "
Three times per week	3	6	1	....	3	......	17	16	18	4	8	....	....	24% "
														100% of collection
Type of receptacles set out:														
Garbage cans	9	5	2	4	2	2	20	17	18	5	6	1	3	17% of all receptacles
Barrels	40	7	4	1	6	3	20	9	16	12	1	3	21	25% " "
Miscellaneous	14	21	3	14	14	13	6	6	4	53	50	65	62	58% " "
														100% of all receptacles

Notes.—(1) Six collections made daily from industrial district. Four collections made five times per week from industrial district. Three collections made four times per week from industrial district.

(2) Frequency of collection noted as irregular. No figures given. Pavements poor, in alleys impassable in winter.

(3) *a*, *b*, *c*, and *d* are different districts.

TABLE 50.—ANALYSIS OF COMPLAINTS REGARDING COLLECTION SERVICE IN WASHINGTON, D. C., IN 1915 AND 1916

Complaints	Garbage				Ashes				Refuse			
	1915		1916		1915		1916		1915		1916	
	No.	Percentage	No.	Percentage	No.	Percentage	No.	Percentage	No.	Percentage	No.	Percentage
Fault of contractor....	51	9	49	11	173	15	130	15	337	22	271	19
Fault of householder..	214	38	132	29	463	42	255	29	640	41	464	32
Doubtful............	291	53	276	60	476	43	484	56	585	37	724	49
Total complaints...	556	100	457	100	1112	100	869	100	1562	100	1459	100
Total requests.....	165	...	111	...	415	...	278	...	316	...	250	...
Grand totals.......	721	...	568	...	1527	...	1147	...	1878	...	1709	...

without effort. Some persons do not seem to understand exactly why or how the separation should be made. In Chicago, Boston, and elsewhere, under the two- and three-can systems, much garbage finds its way to the dumps by way of the ash cans, and some rubbish to the reduction plants in the garbage cans. From the point of view of simplicity and ease of general adoption, the one-can system, as generally practiced in Europe, offers most advantages to the residents, but—in our country—not always to the city treasury.

Of the available systems of house treatment, the one which permits of the greatest cleanliness should be preferred. Garbage generally causes the most nuisance, because of the odor of its putrefaction and from the liquids draining from it, which foul anything with which they come in contact. Both these objections are reduced if the garbage is intermixed with ashes and rubbish. Garbage, stored sufficiently long by itself, always creates a nuisance.

In Milwaukee, in order to keep the foul-smelling garbage wagons off the streets during the day, the collection department has been forced by public opinion to collect garbage at night. Much of the public complaint against selecting certain locations for disposal works is due to the necessary concentration of odorous collection wagons along the routes.

Where garbage has become too old for feeding to hogs, and if the loosely fitting covers of the cans do not prevent odors, it is suggested that chloride of lime, a dilute solution of cresol, a solution with a pine oil base, gas house waste, or sawdust, if available, might be used. When garbage is not yet too old for feeding, but should be disinfected, then powdered charcoal is the most serviceable material. Garbage pails should be washed with water after being emptied, particularly if the garbage is fed. When not fed, disinfection can be effected as above, to serve as a fly repellent.

The greatest nuisance from ashes is the dust which the wind blows from them. Wet or moist garbage mixed with them lessens the volume of dust. The greatest nuisance from rubbish comes from the loose paper which is blown away from the can, wagon, or dump. This is less likely to happen if the rubbish is weighted down with garbage and ashes.

Mixed refuse is less objectionable to handle than garbage alone, and, in this respect, does not differ materially from either ashes or rubbish. Therefore, a better class of labor can generally be secured to collect mixed refuse.

With regard to cleanliness, the European one-can system, therefore, has many advantages.

From the viewpoint of total cost, including the cost of final

disposal, the separation of garbage from ashes and rubbish may be advantageous, particularly in America, where the richer garbage can be used profitably as hog food, and where its percentage of grease is high. This is also true when ashes and rubbish, if kept separated from garbage, do not require to be collected as frequently as do either garbage alone or the mixed refuse. In many communities or districts both ashes and rubbish can be disposed of by themselves, in part or together, at the premises, or by short hauls to near-by dumps. This condition may relieve the collection department of much work, and it will reduce the cost.

The value of the different methods of house treatment, therefore, must be considered in conjunction with the costs of collection and disposal, and will be taken up again later with these subjects. The cost data bearing on house treatment alone are quite inadequate, and difficult to formulate. None is here given.

2. Trade Refuse, Manure, Sweepings, Night-soil, and Dead Animals.—Owing to the great variation in the character and quantity of these materials, no general suggestions can be given as to the treatment at their origin, as this will depend entirely on the local conditions in each case. A few detailed remarks, however, may be of service.

(*a*) *Trade Refuse.*—Trade refuse should receive such treatment and storage at the factory as will prevent any and all nuisances arising therefrom on the premises. Therefore, it will depend entirely on the specific character of the materials. If they are small in quantity and have the character of general rubbish, they may be classed as rubbish and collected by the city in the same receptacle as the domestic rubbish, and in the same manner. In that case the refuse should be placed in similar cans, at suitable points, and for collection at such hours as are fixed by the city. If the quantities are large, the producer should remove them at his own expense, as a part of his business affairs and subject to the special city regulations covering the requirements of sanitation and the comfort of the citizens.

(*b*) *Stable Manure.*—As regards the house or stable treatment, it should be emphasized here that all stable manure should be prevented from becoming objectionably odorous, by providing tight-fitting covers for the pit and by a sufficiently frequent removal, but chiefly from becoming a fly-breeding center. This subject is discussed at length in Chapter XIV.

(*c*) *Sweepings.*—House sweepings consist chiefly of dust, and, where a separate collection is maintained, are usually placed in the rubbish or ash can. It is very desirable, however, in case of infectious diseases occurring in a house, that all sweepings, as well as other rubbish

from sick rooms, be kept out of the rubbish and burnt if possible in the house furnace, kitchen range, or elsewhere on the premises.

(*d*) *Night-soil.*—In localities where there are no sewers, night-soil is usually contained in privy vaults, which are specially built for the purpose, either with open joints to permit the liquids to drain out, or with tight joints requiring both solids and liquids to be pumped out periodically and removed by odorless excavators. (See Chapter XVI.)

There are numerous contrivances in America and Europe, consisting of pails, barrels, *fosses mobiles*, etc., which are placed at the bottom of the soil pipes in a house and receive the droppings. At suitable intervals of time the full receptacles are exchanged for empty ones and removed.

One of the best contrivances for receiving night-soil, in a house for which there is no sewer, is the so-called earth-closet, first introduced in England by the Rev. Henry Moule, in 1863. A sufficiently large pail, barrel, or box, is placed beneath the seat of a closet, a sufficient supply of dry and finely pulverized earth, sawdust, charcoal, loam, or clay—but not sand—is stored in the closet about 5 ft. above the seat, and filled from the outside. A pipe leads from it to the bowl under the seat, and is provided with a valve. By means of a pull, similar to that of a water closet, a fixed quantity of earth, sufficient to absorb the free liquids, is released and spreads over the fresh fæces and by covering them prevents offensive odors. This contrivance has been especially applicable in small towns or suburbs where an opportunity may offer to utilize the material in gardens or on fields.

(*e*) *Dead Animals.*—The dead bodies of horses, dogs, and cats are usually collected from the house or stable by the public departments. The treatment at the house prior thereto should be as follows: As soon as the death occurs, notify the Health Department. Meantime, leave the body in a suitable place for collection, and keep it covered so that no flies or other insects may get to it. Unless the body is removed within twenty-four hours, a good disinfectant must be liberally scattered entirely over it, and the body again covered. (See Chapter XVI.)

G.—EDUCATION OF HOUSE OCCUPANTS

As already suggested, the education of the house occupant to treat properly his own refuse at the house before collection is important. In cities having different classes of inhabitants, from the more careless and uneducated to the most particular, it is very difficult to secure uniform house treatment. Only systematic and persistent efforts along educational lines will approximate the desired result.

Some gain can be secured by uniforming the workmen in the collection service. (See Table 52, in Chapter III.)

The difficulty of maintaining the desired separation of refuse at the house is reflected in the city ordinances of New York, Chicago, etc., requiring that no collection be made unless the householder observes the rules regarding the separation.

H.—SUMMARY AND CONCLUSIONS

The details of the house treatment of refuse discussed in this chapter should serve to show and to emphasize its importance. Specific conclusions pertaining to all conditions cannot be drawn. It is necessary to study this subject carefully, together with a consideration of the organization and routine work of the collection department. The relation of the house treatment to the collection service and final disposal requires more attention in its details than has heretofore been given to it; and, to secure the best treatment, the hearty co-operation of the householders with the department is necessary. This can be obtained only by patient, persistent, and intelligent instruction, as well as guidance, on the part of the officials of the department.

I.—SAMPLES OF CARDS AND RULES

Examples of house cards and rules published by city departments having charge of refuse collection work have been selected from various parts of the country, and are shown on pages 98 to 103. Such cards should be hung up at suitable places, as a constant reminder.

In Springfield, Mass., the collectors report each case where collection has not been made. The form provided for the purpose shows the street, house number and the date, and indicates that the collection could not be made for one of the following reasons: Locked door, walks not shoveled, can not in convenient place, refuse not separated, rickety barrels, frozen barrels, large barrels, builder's rubbish, garbage not on ground floor, garbage not in cans, etc.

SPRINGFIELD, MASS.

READ THIS CARD **KEEP THIS CARD**

REGULATIONS
FOR
Collection of Household Waste

The department will make every endeavor to render efficient service, but will assume no responsibility for loss or damage to property if ashes or rubbish are required to be removed from within buildings.

SEPARATE CONTAINERS

Separate containers must be provided for garbage, ashes, and rubbish, and in no case will collections be made by the City unless the following separations are made:

GARBAGE COLLECTION

Garbage: The term "garbage" means all vegetable matter and table waste.

Containers: Covered water-tight metal cans.

Collections: Twice a week.

ASHES COLLECTION

Ashes: The term "Ashes" includes ashes, floor sweepings, broken glass, discarded kitchen ware, tin cans, and worn-out furniture. No material will be removed that accumulates as the result of building operations.

Containers: Metal cans, or barrels, size not to exceed 18 inches in diameter by 26 inches high; walks leading to containers shall be cleared of ice and snow.

Collections: Once a month in summer and twice a month in winter.

RUBBISH COLLECTION

Rubbish: The term "rubbish" means paper, card-board boxes, rags, bottles, metals, old clothes, shoes, and rubbers.

Containers: Light metal cans, or barrels, canvas or burlap bags.

Collections: Once a month.

Address all complaints to

DEPARTMENT OF STREETS AND ENGINEERING
Waste Disposal Division,
Administration Building, Springfield, Mass.

Telephone R 6100

CLEVELAND, OHIO.

How to Help Keep Our City Clean

Suggestions to Householders Relative to the Collection of Ashes, Rubbish, Waste Paper and Garbage.

ASHES AND RUBBISH

The collection of ashes and rubbish is provided only in households.

In order to facilitate and make possible a thorough and efficient collection of ashes and rubbish householders should provide suitable receptacles with handles and covers, and place the ashes and rubbish therein. These receptacles should not be larger than can be carried conveniently to the wagon after they are filled. If there is refuse that cannot be placed in the receptacles then this material should be tied in bundles.

No ashes or rubbish will be removed from basements. All materials to be removed by the city must be kept in a place that will make its collection convenient.

Never place garbage, vegetables or other offensive material in the same receptacle with ashes and rubbish. Bottles, tin cans, etc., should be placed with the rubbish and ashes and not with garbage. Rubbish accumulated in yards—such as grass, leaves, twigs, shrubs, etc., if not too bulky to be handled, will be taken.

WASTE PAPER

Waste paper will be removed from business places, apartment houses, households and other places provided it is kept in bags or tied in bundles. Waste paper must always be kept in a dry place.

In order that waste paper may be kept dry, and to prevent it from blowing about the premises and streets, it will be removed from basements or sheds, but collectors will not enter basements unless the occupant of the house is present and gives his or her consent. If paper is kept in the basement it should be in a convenient place, and should be near the foot of the stairs.

GARBAGE

All garbage must be placed in a metal receptacle, which shall be provided with a top or cover. For a family of ordinary size a garbage receptacle holding 10 gallons is recommended.

It is against ordinances regulating the public health to throw garbage into the streets or allow the same to remain exposed and not in a proper receptacle.

Do not deposit anything in the garbage can except vegetable matter, table refuse, etc.

No collector of any of the city divisions is permitted to accept any remuneration from any householder. Any collector accepting a remuneration will be dismissed from the service.

Householders are requested to report any inattention on the part of collectors of ashes, rubbish, waste paper and garbage to the Complaint Department, 314 City Hall, Main 4600 Station 6 or Central 1 Station 6.

By complying with these rules you will aid the city administration in its efforts to make Cleveland a healthier, cleaner and better city in which to live.

Let us all do our part.

Very respectfully,

HARRY L. DAVIS, Mayor

MILWAUKEE, WIS.

Hang this card in your kitchen

AND

"CLEAN THE CAN"

CITY OF MILWAUKEE

DEPARTMENT OF PUBLIC WORKS

GARBAGE COLLECTION

RULES.

1. Provide *Metallic* cans having *Tight* fitting covers and handles on the sides. (Size about 20 gallons).
2. Provide enough cans to hold 1 week's accumulation of garbage.
3. Place the cans on the *Ground* floor, where easily found.
4. First *Drain* the garbage of all water.
5. Then *Wrap* the drained garbage in a piece of old newspaper.
6. Put only *Drained* and *Wrapped* garbage in the garbage can. No other refuse will be removed by the garbage collector.

REASONS.

1. Garbage is the animal and vegetable waste from kitchens. When rotten it smells and breeds flies. Fresh garbage is inoffensive. Only soiled, wet garbage, in dirty, open cans, becomes foul. Wooden pails or boxes soak up the foul juices from the garbage and become foul. Uncovered cans attract the flies and hasten decay. Unclean cans are a menace to health and will be reported to the Health Department.
2. Garbage is collected by the department once in seven days. If this is not done, complaint should be made to *'phone No. 4* City Hall *(Main 2595).* Be sure that your complaint is legitimate Unnecessary complaints waste time and money. As garbage is collected at night look into the can before complaining. If you burn the combustible garbage in your stove or furnance, the garbage will not accummulate.
3. Place the can in a *Regular,* easily found place, where the collector can always get it. Do not keep your gate locked. If you have a watch dog, chain him up. Help the collector and co-operate with the department.
4. Keep the garbage wrapped and drained. It will not stick to the can in any weather and the can will not become foul. Most of the nuisance from garbage starts in the garbage can. Garbage, when foul is generally so because decay has been started by the dirty open, uncovered can.
5. Flies are a nuisance and carry disease. They should be exterminated. They breed in garbage. Wrap the garbage so that the flies can not lay their eggs in it.
6. The garbage wagons are not equipped at present to collect anything but garbage Therefore only wrapped and drained garbage must be put in the garbage can.

54 "CLEAN THE CAN"

MINNEAPOLIS, MINN.

CITY ENGINEER'S DEPARTMENT

F. W. Cappelen, City Engineer

DIVISION GARBAGE COLLECTION

RULES

Pertaining to the Collection of Garbage

1. The garbage of Minneapolis is collected under the direction of the City Engineer and by the authority of the City Council. (See Resolution passed January 8th, 1915.)

2. The owner or occupant of each house is required by law to provide metallic cans, with close-fitting covers, and with handles upon the sides.

3. Provide a sufficient number of cans to hold at least seven days' accumulation. Cans must be placed on the ground floor, near the alley, easily accessible to the collector, and when filthy, leaking, or in any way defective, be replaced by new cans. Garbage cans must be of a 20-gallon size.

4. Drain garbage of all moisture, then wrap it in paper before putting it in the can, and it will neither smell badly in hot weather, nor freeze or stick to the can in cold weather.

5. Put into the garbage can all animal and vegetable refuse from the kitchen, rags, waste paper, old shoes, rubbers, floor sweepings, and all miscellaneous refuse that will burn. Garbage cans, containing water, slops, ashes, tin cans, glassware, crockery, or manure, will not be emptied by the collector.

6. Report all dead animals to this Department, giving exact location of same.

7. Please do not ask the collector to do your janitor work. He is paid a salary, and his time belongs to the City.

8. You are not entitled to the service of this Department unless you conform to these rules.

9. After you have complied with the above rules, report all complaints to the Plymouth Avenue Station.

T. B. BUCKLEY, N. W. Phone, Nicollet 6261.
Supt. of Garbage. Tri-State, North 1368.

HANG THIS UP IN YOUR KITCHEN.

WINNETKA, ILL.

HANG THIS CARD IN YOUR KITCHEN FOR REFERENCE

VILLAGE OF WINNETKA
Garbage, Ash and Rubbish Service

NATURE OF SERVICE

Section 241 of the Village Code of Ordinances requires

"That each occupier of premises in the Village of Winnetka shall remove from his premises or otherwise dispose of all garbage, ashes, tin cans and metal ware, broken glass and crockery and stone ware, and all refuse of every description whatsoever, and keep his said premises at all times free and clear of any accumulations of garbage, ashes, tin cans and metal ware, broken glass and crockery and stone ware and all refuse of every description whatsoever."

Regular collections of garbage and ashes are made by the Village for a monthly charge, based on the number of rooms in your residence. The charge for a five-room residence is $0.75 per month and increases $0.25 for each additional room. Call Winnetka 54 for information.

Tin cans, bottles and other refuse are collected universally throughout the Village free of charge out of funds provided by the special two mill tax. Garbage, ashes and rubbish are each collected in specially designed vehicles in order to make the service clean, sanitary and unobjectionable.

TIME OF COLLECTIONS

(Postal card notice will be given of changes in this schedule.)

Garbage.......Monday, Wednesday and Friday of each week.

Ashes.......Wed & Fridays

Rubbish.......On Friday of every other week.

IMPORTANT—Place your receptacles where the collector can reach them easily on the days noted above. This will help us to improve your service.

RULES AND REGULATIONS

These regulations are based on the Village Garbage Ordinance and must be carefully observed. They are designed to protect your health and to give all an efficient service.

Separate receptacles must be provided for each of the following:

1. Garbage.
2. Ashes.
3. Tin cans, bottles and other refuse.

It is very important that each of the three foregoing classes be kept carefully separate.

Garbage receptacles must be metal cans, so that they may easily be washed, and must be provided with a tight fitting cover. **Keep your garbage can clean at all times.**

Garbage should be drained and wrapped in paper in cold weather to prevent freezing to the can.

Ashes should be placed in cans or other receptacles which can be easily handled by the collectors.

Receptacles should be placed at a convenient point outside the building, on the day when your collection is made. An observance of this rule will greatly improve the regularity of your service. Time required for collections is nearly doubled when receptacles are kept inside.

Paper will be collected with rubbish if desired. It is expected, however, that all who can will save magazines, newspapers and old books for the Boy Scouts.

Collectors are not allowed to spend time in picking up refuse which has not previously been placed in receptacles.

Remember the collector's time is valuable. Efficient service can only be rendered by cooperation on the part of the householder.

Collectors are instructed to be courteous at all times. Any incivility should be reported to the Village office at once.

Householders are requested to instruct their help in the observance of these regulations.

VERY IMPORTANT—Householders leaving the Village, or who for any other reason wish service discontinued, temporarily or permanently, should notify the Village office to that effect. Neglect to do this causes much unnecessary misunderstanding about the period which our bill for service should cover.

MONTCLAIR, N. J.

Resolution Regarding Ashes and Garbage Collection

WHEREAS, By ordinance adopted May 20th, 1906, it was ordained that ashes and garbage made and produced within the limits of the Town of Montclair should be collected, removed and disposed of at public expense in such manner as the Council shall from time to time by resolution or vote of the majority of said Council determine; now be it

Resolved, That the following rules and regulations are hereby adopted for the collection of ashes and garbage in the Town of Montclair.

RULES AND REGULATIONS FOR THE COLLECTION OF ASHES AND GARBAGE IN THE TOWN OF MONTCLAIR.

ASHES: All ashes for public collection must be placed in metal containers which when filled will weigh not over one hundred pounds and must be placed outside the building and within twenty feet thereof.

Ashes must be free from tin cans, paper and rubbish of every description.

GARBAGE: Garbage for public collection must be placed in containers acceptable to the Board of Health and must be placed outside of the building and within twenty feet thereof.

Garbage consists of waste foodstuffs only and must be free from tin cans, paper and other rubbish of every kind.

GENERAL REGULATIONS: After a snow fall of five inches or more, ashes and garbage will not be collected from premises where a path at least two feet wide is not shovelled from the street to the location of the ash or garbage cans. Where use of driveways is refused to wagons, ash and garbage cans must be placed at the curb line of the street.

Ashes or garbage placed in underground receptacles will not be collected by town men, but the ash or garbage can must be taken from the receptacle by the resident and placed above the ground in a location as noted above. Collectors are allowed in no case to enter buildings or parts thereof for the collection of ashes or garbage.

Citizens are requested not to offer collectors gratuities as men apprehended in accepting such will be immediately discharged.

Citizens are requested to make all complaints to the Town Engineer's office instead of attempting to negotiate with the collectors. Telephone 2786 Montclair.

Property owners will greatly facilitate the collection of both the ashes and garbage by complying with the above regulations and by having the ash and garbage cans out in the proper location on the regular days for collection.

Conditions permitting, two collections of ashes each week are made during the winter months, and one collection during the summer months, and two collections of garbage each week throughout the year.

Section 6 of the sanitary code of the Board of Health reads as follows:

Section 6. All garbage and offal which shall accumulate anywhere in the Town of Montclair, or which is stored, kept or retained therein, shall be kept in water-tight iron or steel receptacles provided with tightly fitting covers, all properly treated to prevent corrosion.

Adopted by Town Council April 13th, 1914.

HARRY TRIPPETT,
Town Clerk.

CHAPTER III

COLLECTION

The collection of refuse is an intermediate process between the house treatment and the final disposal. In some respects it is the most important of these three parts of the problem. Many people are affected by it more directly than by the other two parts, and the cost of collecting municipal refuse is normally larger than that of the disposal. This branch of service becomes more important the larger the city, but it has been frequently unsatisfactory in its results. The best solution must be based on the special conditions of each case, and is practically an engineering problem of plant, power, and time; it cannot be obtained by copying other cities or by blindly accepting the claims of those who are financially interested.

Conveying the refuse from the points of origin to those of final disposal is divided into two parts: One pertains to the actual collection or gathering of the refuse from the houses into the wagons, and the hauling of it to proper places for subsequent transportation or direct delivery to places of final disposal; another part pertains to the transportation of the refuse by secondary means after the original collection. Such secondary methods include transportation by barges, motor trucks, street railways, and railroad cars, and are not now required in all communities, but their use is increasing in the larger cities.

The subject of collection is discussed in the present chapter. The subject of transportation by secondary methods is discussed in Chapter IV.

A.—REPORTS AND EARLY CONCLUSIONS

Until quite recently the details of the collection service had rarely received the consideration from city officials which its importance deserved on account of both cost and sanitary efficiency. Only within the last few years have engineers succeeded in focusing attention on this subject. The matter was first given scientific considera-

tion by the Garbage Committee of the American Public Health Association. This Committee, in 1890, sent out, in pamphlet form, a questionnaire on refuse disposal, in which the subject of collection was very carefully covered by 27 items. From time to time the matter has received additional study. In a paper before the International Engineering Congress, held at St. Louis in 1904, appears the following statement by Hering on the collecting of refuse.*

"It will be evident that the method of collecting the materials just described also forms an important part of the work under discussion. Not only will the objectionable qualities of the refuse require special precautionary consideration and special methods of handling, but the element of cost of transporting alone sometimes becomes sufficiently important to decide the method of final disposal. Great distances for hauling may act against the economy of operating a single plant. Conversely, the method of disposal to be adopted sometimes controls the necessary manner of collection."

An efficient and faithful collection service, depending primarily on a scientific study and an economical as well as effective organization, can be secured only through the entire separation of the department activities from the frequently changing political organization in some of our American cities. The necessity for an intimate familiarity with the routes, the location of the cans, the habits and propensities of the individual householders, the complexities of the materials to be gathered and conveyed, with their tendencies to create nuisances through odor and dust, if not properly handled at proper times, requires long experience and adequate training. The force employed, therefore, should be as nearly permanent as practicable, and the men in the department should be encouraged, by a reward for the best work, either by promotion or increase of pay.

For these reasons city refuse collection should only be done by contract when the municipal department is known to be wholly incapable of doing the work, because of inexperienced or inefficient employees. In all well-managed cities of Europe, with a longer experience than ours, municipal refuse is collected only by force account with well-trained men. The results are high efficiency and economy, and, generally, thorough satisfaction to the public as well as to the occupants of houses.

Within the last few years further careful thought has been given to the subject of refuse collection, and several important reports have been made. The first one in which this subject was isolated from the

* *Transactions*, Am. Soc. C.E., Vol. LIV, Part E (1905), p. 281.

general refuse problem was presented to the Western Society of Engineers in September, 1913.* From this report the following is quoted:

"Of the three divisions of refuse disposal work, the collection is the most important, for the following reasons:

"(1) It is the most costly. Table 51 shows the cost of collection and disposal, chiefly for garbage, in a number of American cities. From this table it is evident that the cost of collection varies from two to eight times the cost of disposal. The house treatment involves no common cost to the community, but against all householders comes the cost of the house can and its up-keep.

TABLE 51.—COMPARATIVE COST OF COLLECTION AND DISPOSAL

City	Year	Material	Cost per Ton		Authority
			Collection	Disposal	
Albany, N. Y.......	Estimated	Mixed refuse	$1.84	$0.41	Wallace Greenalch
Richmond Borough, New York City...	1911	Mixed refuse	1.64	0.54(1)	J. T. Fetherston
Seattle, Wash.......	Estimated	Mixed refuse	1.30	0.62	George H. Moore
Boston, Mass.......	1910	All refuse	1.41	0.43	Annual Report
Buffalo, N. Y.......	1907	Garbage	2.19	....	F. G. Ward
Chicago, Ill.........	1911	Garbage	3.42	0.38	S. M. Singleton
Cleveland, Ohio.....	1911	Garbage	2.83	1.04(2)	W. J. Springborn
Columbus, Ohio.....	1911	Garbage	1.88	0.77(2)	E. W. Stribling
Milwaukee, Wis.....	1910	Garbage	2.85	0.90	Annual Report
Minneapolis, Minn...	1910	Garbage and ashes	1.32	0.92(3)	Annual Report
Buffalo, N. Y.......	1907	Rubbish	4.90	0.04(4)	F. G. Ward
Averages......	....	......	$2.42	$0.60	

Notes.—(1) Estimated from cost per cubic yard.
(2) Profit.
(3) Cost of garbage disposal only.
(4) Cost after deducting profit from rubbish sorting plant.

"(2) More numerous complaints arise from the failure of the collection service than from the house treatment or the disposal of refuse. At Milwaukee, during two years, Greeley found that only three complaints were received against the disposal system, whereas the complaints against the collection service ranged from five to fifty per day, being more in summer and less in winter.

"(3) The collection service affects more people more directly than does the disposal part of the work. An unsanitary point of disposal is generally in an isolated place where it affects but few dwellings and comparatively few people. On the other hand, failure to provide frequent collection service affects directly

* *Journal*, Western Soc. Engineers, Vol. XVII, No. 9.

ervice Commission of Chicago, 1913.)

Garbage Collection and Removal

	Type of wagon used	Kind of cover	Method of unloading	Disposition	No. of auto trucks for removal of waste
Alb	Iostly barrels on wagons	....	....	Piggery	None
Bal	Iigh sides, covered tops	....	Rear dump	Reduction	One
Bos	and 2-horse wagons	Steel	Automatic rear-dump	By contract	One
Chi	-horse; steel box	Steel	Derrick	Reduction	None
Cin	ron boxes	Steel	Lever dumping	....	None
Cle	Rear-end dump-wagon	Canvas	Dumped	Reduction	None
Col	Special wagon hand-hoist	Canvas	Hand hoist	Reduction	None
Det	Single wagon, steel boxes	Canvas	Boxes put on flat cars by electric crane	Private reduction company	None
Gra	teel tanks	Steel	Electric hoist to cars	Cremation and piggery	None
Ind	....	....	Self-dumping	Reduction	None
Ka	Vood tanks	Wooden	....	Fed to hogs	....
Mi	teel tanks	Canvas	Hoisted by crane	Incinerated	One
Mi	ron boxes	Iron	Hoisted by crane	Incinerated	None
Ne	arts	....	Self-dumping	Dumped	None
Ne					
	teel carts	....	Self-dumped	Reduction	None
	teel carts	Canvas	Self-dumped	Cremation	None
	ron carts	....	Self-dumped	Reduction	None
	arts	....	Self-dumped	Incineration	None
Om	ron boxes	....	....	Piggery	....
Po	Dump-wagons	Canvas	Hand-dumped	Incineration	....
Phi	Ietal bodies, rear-dump	Metal	Dumped rear	Reduction	None
Pro	teel boxes	Wood	Shoveled out	Piggery	None
Roc	teel wagons	Canvas	Tipping-bottom, rear dump	Reduction	One
San	Ietal-lined, water-tight box	Metal	Rear-dump	Privately owued destructor	None
Sea	Vooden wagons	....	Dumped	Incinerator	Five trucks
St.	ank-wagons	Iron	Rear-dump	In river	None
Tol	Ietal tanks	Metal and canvas	Derrick	Reduction by contract	3 trucks to haul from loading station
Wa	teel removable bodies	Steel	Derrick	Reduction	....

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Table 52.—Data from American Cities Regarding Refuse Collection and Removal. (From Report of Civil Service Commission of Chicago, 1913.)

City	Population	Uniforms				No. of separations of refuse	Rubbish and Ash Collection and Removal				Garbage Collection and Removal						
		Kind	Life, in months	Furnished by	Washed by		Rubbish and ashes collected by	Method of hauling	Method of unloading	Disposition	Collector	Method of hauling	Type of wagon used	Kind of cover	Method of unloading	Disposition	No. of auto trucks for removal of waste
Albany, N. Y.	100,253	None	......	....	....	....	Private collectors. Not by city	....	....	Dumps	Private collector	....	Mostly barrels on wagons	....	....	Piggery	None
Baltimore, Md.	558,485	White duck	......	Laborers	Laborers	Dual	City	Carts	From rear axle	Dumps	City	Carts	High sides, covered tops	....	Rear dump	Reduction	One
Boston, Mass.	670,585	Khaki	6	City	Laborers	Triple	Contractor	Wagons	Wagons dumped	Contractor	Contractor	Wagons	1 and 2-horse wagons	Steel	Automatic rear-dump	By contract	One
Chicago, Ill.	2,307,638	None	......	....	....	Dual	City	Wagons	Hand	City dumps	City	Wagons	2-horse; steel box	Steel	Derrick	Reduction	None
Cincinnati, Ohio	363,591	None	......	....	....	None	City	Carts and wagons	Lever dumping	Dumps	City	Wagons	Iron boxes	Steel	Lever dumping	....	None
Cleveland, Ohio	560,663	White canvas	......	Laborers	Laborers	Triple	City	Dump-wagons	Drop-bottom wagon	Dumps	City	Rear-end dump-wagon	Rear-end dump-wagon	Canvas	Dumped	Reduction	None
Columbus, Ohio	181,511	None	......	....	....	Triple	City	Dump-wagons	Lever dumping	Dumps	City	Wagons	Special wagon hand-hoist	Canvas	Hand hoist	Reduction	None
Detroit, Mich.	465,766	White cotton	......	Laborers	Laborers	Dual	City	Wagons	Hand labor	Dumps	City	Wagons	Single wagon, steel boxes	Canvas	Boxes put on flat cars by electric crane	Private reduction company	None
Grand Rapids, Mich.	112,571	Khaki	6	Laborers	Laborers	Triple	Private individuals	Wagons	Dumped from wagons	Dumps	City	Steel tanks on wagons	Steel tanks	Steel	Electric hoist to cars	Cremation and piggery	None
Indianapolis, Ind.	233,650	None	......	....	....	None	Contract	Wagons	....	....	Contractor	Wagons	....	....	Self-dumping	Reduction	None
Kansas City, Mo.	248,381	White and brown duck	2	City	Laborers	None	Individuals	Wagons	....	Used for filling	Contract	Wagons	Wood tanks	Wooden	....	Fed to hogs	....
Minneapolis, Minn.	301,408	White duck	3	Laborers	Laborers	......	Individuals	....	....	Dumps	Contract	Steel tanks on wagons	Steel tanks	Canvas	Hoisted by crane	Incinerated	One
Milwaukee, Wis.	373,857	White duck	6	Laborers	Laborers	None	City	Wagons	Bottom-dump	Dumps or incineration	City	Single wagon	Iron boxes	Iron	Hoisted by crane	Incinerated	None
New Orleans, La.	339,075	White duck	......	Laborers	Laborers	None	City	Carts	Hand labor	Dumps	City	Carts	Carts	....	Self-dumping	Dumped	None
New York:																	
Manhattan	....	White duck	12	Laborers	Laborers	Triple	City	Carts	Hand labor	Land fills	City	Carts	Steel carts	....	Self-dumped	Reduction	None
Queens	284,041	White canvas	12	Laborers	Laborers	Triple	City	Carts	Hand labor	Inland dumps	City	Carts	Steel carts	Canvas	Self-dumped	Cremation	None
Bronx	430,980	White duck	6	Laborers	Laborers	Triple	City	Carts	Hand labor	Land fills	City	Carts	Iron carts	....	Self-dumped	Reduction	None
West New Brighton	85,969	White duck	12	Laborers	Laborers	None	City	Carts	Hand labor	Incineration	City	Carts	Carts	....	Self-dumped	Incineration	None
Omaha, Nebr.	124,096	White canvas	......	Laborers	Laborers	......	City	Wagons	Hand labor	Dumped on low ground	City	Wagons	Iron boxes	....	....	Piggery	....
Portland, Ore.	207,214	White duck	10	City	City	......	Contract	Wagons	Hand labor	Dumped in fills	Contract	Wagons	Dump-wagons	Canvas	Hand-dumped	Incineration	....
Philadelphia, Pa.	1,549,008	White duck	......	Contractor	Contractor	Triple	Contract	Wagons	Back dump	Dumped	Contractor	Wagons	Metal bodies, rear-dump	Metal	Dumped rear	Reduction	None
Providence, R. I.	224,326	Khaki	6	City	Laborers	......	Privately	....	....	....	Contractor	Wagons	Steel boxes	Wood	Shoveled out	Piggery	None
Rochester, N. Y.	218,149	None	......	....	....	Triple	Contract	Wagons	Dump-wagons	Burned or sold	Contract	Wagons	Steel wagons	Canvas	Tipping-bottom, rear dump	Reduction	One
San Francisco, Cal.	416,912	None	......	....	....	None	Contract	Wagons	Dump-wagons	Land dumps	Contractor	Wagons	Metal-lined, water-tight box	Metal	Rear-dump	Privately owned destructor	None
Seattle, Wash.	237,194	....	......	....	....	None	City	Wagons	Dumped	Incineration	City	Wagons	Wooden wagons	....	Dumped	Incinerator	Five trucks
St. Joseph, Mo.	77,403	White duck	3	Laborers	Laborers	Dual	Contract	Wagons	Rear dump	In river	Contract	Wagons	Tank-wagons	Iron	Rear-dump	In river	None
Toledo, Ohio	168,497	White and brown duck	12	Laborers	Laborers	Dual	City	Wagons	Rear dump	Dumped in low lands	City	Wagons	Metal tanks	Metal and canvas	Derrick	Reduction by contract	3 trucks to haul from loading station
Washington, D. C.	331,069	White duck	......	Laborers	Laborers	Triple	Contract	Wagons	Hand labor	Incinerated, sold, or dumped	Contract	Wagons	Steel removable bodies	Steel	Derrick	Reduction	....

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the people who should receive the service and their neighbors as well. Failure to make collections makes necessary the accumulation of decomposable refuse in the back yard, which may create a nuisance for people living in the same block."

In the same year, the Bureau of Economy and Efficiency, at Milwaukee, published a bulletin entitled "Garbage Collection." The field studies for this report included detailed time studies of the collection wagons, to determine the number of collections which could be made by a wagon of given capacity, the rate of travel, the number of loads per day, and other special elements of the collection service. The report comments adversely on night collections, and makes a strong plea for washing and disinfecting the wagons at frequent intervals. The frequency of garbage collection recommended is as follows:

Winter collections: Business section, 5 times a week; all other sections, once a week.
Summer collections: Business section, 6 times a week; all other sections, twice a week.

Reports have been made by Hering and Gregory for Trenton and Dayton, in which the details of the equipment required and its operation for different methods of disposal were carefully worked out and included in the estimates of cost for various projected methods of disposal.

More recently, the question of collection has received special consideration in Chicago. The 1913 report of the Civil Service Commission on the Bureau of Streets, gives much information relative to the local methods of collecting garbage, ashes, and rubbish. It contains a table, with data from a number of cities, relating to the collection service. Table 52 has been made up from the data contained in this report collected from 25 cities. It also covers uniforms.

Following the previous report, the City Waste Commission of Chicago secured, from Messrs. Osborn and Fetherston, a report on the refuse problem which discusses the collection of refuse, as follows:

"In any method adopted for the collection of refuse, there are four requisites for success:

"1. A sufficient appropriation.

"2. An efficient organization.

"3. Sanitary and economical methods of work.

"4. Co-operation on the part of the public.

"The first essential is self-evident, for, in order to render satisfactory service, sufficient funds must be provided to carry out the work. The appropria-

tion will be regulated to a large extent by the degree of success obtained in the development of the other three requisites.

"An efficient organization cannot be maintained without a sufficient appropriation, neither can work be conducted satisfactorily or economically without an efficient organization and a sufficient appropriation. Co-operation on the part of the public cannot be expected without rendering satisfactory service. All four requisites are dependent on each other to obtain the maximum degree of success."

These and other investigations and reports have resulted in more serious attempts on the part of the cleansing superintendents to improve the collection service. This result has been reflected recently in more systematic and complete annual reports by department chiefs and in more comprehensive and careful specifications under which bids for collection work have been asked.

B.—METHODS OF COLLECTION

The collection of refuse must be controlled by two main requirements: No odor; no dust.

In the cities of America and Europe, one finds a great variety of methods and equipments for collecting refuse. Many styles of wagons for garbage and ashes are in use, and their capacities in America range from 1.5 to 6.0 cu. yd. The wagons are sometimes covered and sometimes open. The interval between collections varies from daily to once a week, or much longer for ashes and rubbish. Methods for keeping the wagons clean are more conspicuous by their absence than by their existence. Cleaning wagons is more important in America than abroad, because here it is a frequent practice to collect garbage separated from ashes and rubbish. To keep clean those wagons in which raw garbage is collected requires frequent and regular attention.

It is significant that in Europe, in general, there is a better collection service than in America, and more uniform methods are used. Almost everywhere there are in use large steel wagons holding from 3 to 5 cu. yd., and having fixed covers. The collections are made at least three times a week, garbage, ashes, and rubbish, as stated in Chapter II, being generally combined and collected in the same wagon. The work is often done at night, the householder having set the refuse can out on the curb in front of the house in the early evening. The collection wagons are washed daily. In both countries horses, gasoline, electricity, and steam are the powers used for the collection. Horses have been used from the earliest times, and still have their value and preference under certain conditions. Motor trucks have been driven by gasoline, electricity, and steam. The

steam wagons have disappeared, as being less simple than either gasoline or electricity. Between gasoline and electricity, the former is the more simple and reliable, and therefore is preferred in most cities, except where electricity can be obtained very conveniently and cheaply.

C.—RELATION OF COLLECTION TO HOUSE TREATMENT AND FINAL DISPOSAL

An intimate relation exists between the various parts of the refuse problem of a municipality. The organization of the collection service must satisfy the popular needs. Special requirements of the different classes of people living in different districts of the city, and the influence of the seasons must be considered. Both the sanitary efficiency and the cost depend to a marked degree on the householders. (See Chapter II.) Investigations and reports, looking to a better service, which do not distinctly consider the requirements of householders and the available methods for fulfilling these requirements, fail in this important part of the service. Regularity of the service, uniforming the employees, arranging time schedules for visiting the houses, and many important details should be included in such investigations. Further, the suppression of noise, odors, and dust from collecting wagons, both night and day, is necessary to satisfy the public.

One of the difficult points to settle concerning the garbage collection is the proper location of the can. (See Chapter II.) Sometimes the cans are kept in places where the collector cannot find them readily. This is more apt to be the case in districts populated by foreigners. It is advisable to employ an inspector of the same nationality as the people in such districts, and his chief duty should be to promote co-operation between the householder and the collection department. An improvement of the appearance of back yards and alleys often follows carefully planned educational work of this character.

In some communities, methods of refuse disposal have been adopted and disposal works built in advance of a study of the best general collection service. In such cases, the character of the collection is influenced to a great extent by the method of disposal, sometimes requiring special wagon-bodies suitable for the necessary unloading equipment at the disposal plant. The adopted method of disposal may add materially to the collection cost.

In small cities where the population per acre is small it may often be quite unnecessary to have a public collection of ashes, rubbish, and manure. Garbage may be the only material requiring

collection. Then, particularly if the houses are far apart, small garbage wagons of special design may be more suitable than large ones.

Householders in Buffalo are required to make three separations: Ashes and floor sweepings are placed in one receptacle, garbage in another, and rubbish in the third. All receptacles must be left in places accessible to the contractor's men, and these men bring them to the curb, and, after they are emptied, return them to their original places. All rubbish is owned by the city, and is carted by the contractor to the city's rubbish utilization plant, where it is sorted. All material of no commercial value is burned in the furnace, and helps to generate steam for the city's sewage pumping plant.

In Salt Lake City, at first, the separation was not very satisfactory, but it is being improved by educational work through publicity in the newspapers, by collectors and other agents of the contractors, and, where needed, through tagging the garbage receptacle with a 5½ by 7-in. buff-colored card of explanation, headed boldly, " This Receptacle is Not Emptied for the Reason that the Garbage and Waste Matter is Not Properly Separated," followed by instructions which, if observed by the householder, will ensure collection. The separation is rapidly improving.

D.—GENERAL CONDITIONS

Before discussing in detail the chief elements which control the collection, haul, and delivery of municipal refuse, it is necessary to consider certain general conditions which influence the work of collection in an indirect way.

1. Quantity of Materials.—The quantity of refuse materials produced depends on the habits of the people making up the community and on the season of the year. The unit quantities of the various refuse materials produced under different conditions have been stated in Chapter I. The quantity produced at each house influences the collector's work. It is not economical for a collector to make a trip from the backyard to his wagon regularly with two or three small cans from the same place at one visit. Therefore the size of the can and the interval between collections should be planned so that at each visit the collector will remove one can practically full of refuse.

The schedule of operations should be varied to meet also the seasonal fluctuations in the quantity of refuse. Often this can be accomplished by providing wagons of different capacities. A proper use of wagons of different sizes, with variations in the route and in the

frequency of collection from season to season, can sometimes be made advantageously.

Communities producing more refuse will have a correspondingly greater cost for collection. In Europe it is estimated that an average of about 0.04 cu. ft. of combined house refuse is produced per capita per working day; in American cities the quantity averages about 0.10 cu. ft. or $2\frac{1}{2}$ times as much. Therefore, the collection departments in American cities must take away more than twice as much refuse as is removed in European cities from the same population. American cities, by the way, are obliged to remove also more than twice as much sewage.

The actual quantities of garbage collected in several cities where fairly accurate records are known to have been kept, have ranged from 0.20 to 0.53 lb. per capita per working day of 310 days per year, the present average being not far from 0.50 lb. and 0.70 lb. per day during the maximum month, but the maximum day during the year will exceed this figure.

2. Character of Materials.—The composition and character of a city's refuse, as collected, is determined by the degree of separation at the house, the weather, and the habits of the people. Mixed refuse is a fairly dry material in which the garbage is largely obscured by the rubbish and ashes. Such a material is less objectionable to handle than raw garbage. Three separations, as occasionally found in America, generally require three different kinds of wagons, and the collection work is correspondingly complicated.

3. Climate.—In cold climates, during the winter, garbage does not decompose as rapidly as in summer, and, as smaller quantities are produced at such times, the interval between collections can be increased. In southern cities, warm most of the year, more frequent winter collections are necessary. To some extent, the climate influences also the type of wagons which should be used. Where heavy snows are frequent, hauling becomes more difficult, and large wagons cannot well be used for continuous service.

4. Pavements and Grades.—The team haul in refuse collection is affected materially by the character of the pavements and the steepness of the streets. It is sometimes possible, by proper routing, to have the collection wagons make their trips up hill when empty and down hill when full. From this point of view, collection work may be actually lighter in a hilly city than in a flat one. In flat cities intersected by watercourses, the bridges are frequently raised above the street grade, and the size of the load which might be carried on a level over the greater part of the way must be reduced on account of the up-hill haul at the bridge approaches. The weights which can be

hauled by one horse up different grades, and over good, hard pavements, are as follows (data by J. B. Potter):

Grade percentage.............	0	1	2	2.4	3.3	4	5
Net load for one horse, in pounds	4000	3600	3240	2880	2540	2000	1600

E.—DETAILED CONDITIONS AND REQUIREMENTS

The prime consideration, in order to give satisfaction in refuse collection, is to secure the most sanitary and economical service, from the viewpoints of the householder and of the community as a whole. The efficiency of the service results largely from the individual ability of the men of the organization, and is increased by improved standards of operation and individual work. The element of cost is influenced by the kind of equipment used and the general rules of operation of the department.

The cost can be analyzed more readily than the efficiency of the service. This is particularly apparent when laying out the schedules of equipment and operation for new works. The estimates of cost can be made with a fair degree of certainty, when properly realizing all the detailed conditions which affect the work. The two principal items of cost relate to the loading and hauling. The efficiency depends largely on the human element.

The cost of collection will vary in different communities, depending on the scale of wages, hours for work, the efficiency of labor, and other items. Combined collection is cheaper because but one type of wagon is used, and the same territory requires but one trip. Direct cost comparisons, therefore, are difficult to make. A better basis of comparison in different cities is the determination of the number of collection wagons of given capacity per unit of population. Still other conditions, such as frequency of collection and the time required to make collections from each house, also influence the cost. However, the best bases for comparison are records of man-hours and ton-miles, as they are independent of wages and the length of the working day. Unfortunately, such records are, as yet, rarely made.

All these conditions should be viewed in their proper relations. It is convenient, first, to consider the various special conditions affecting the number of collection wagons required in the service, because the total cost of collection can then be determined from that number.

1. Frequency of Collection.—The interval between collections is one of the factors which determine the quantity of refuse that should be collected each time at each house. The interval should be sufficently short to prevent nuisance, satisfy the householder, and give

opportunity for approximately one full can of refuse to accumulate. From hotels and restaurants the collection should be made daily. The frequency of collection in various cities in America and abroad is as follows:

New York.—In the built-up districts of Manhattan, The Bronx, and Brooklyn, the collections are made six times a week. In the outskirts the collections are less frequent. In the Borough of Richmond the collections are uniform throughout the year, daily in the more populated districts and three times a week in districts where the population is not so dense. In the Borough of Queens collections are made every day in summer and every other day in winter, except in thickly populated areas, where daily collections are made.

Philadelphia.—Garbage is removed six times a week from all buildings in the built-up districts throughout the year.

Buffalo.—Garbage, ashes, and rubbish are collected daily, all the year round, from the business section. From the remainder of the city, they are collected twice a week from May to November, and once a week from November to May.

Milwaukee.—Garbage collection varies from daily for hotels and restaurants to weekly for residences, throughout the year. Ashes and rubbish are collected about twice a month.

Minneapolis.—Garbage, ashes, and rubbish are collected weekly, except from hotels and restaurants, where the collection is more frequent. The garbage is all wrapped in paper to retard its decomposition.

Rochester.—Garbage is collected daily (except Sundays), in the central portion of the city, from May 15th to October 15th, and three times a week in the remaining part of the city; from October 15th to May 15th, twice a week in the central portion of the city, and once a week in the remainder. Mixed ashes and rubbish are collected weekly through the fall, winter, and spring, and semi-weekly in summer.

Denver.—Garbage is collected once a week in winter, and three times a week in summer.

Columbus.—Garbage is collected weekly from November to May, and twice a week from May to November. Garbage and rubbish are collected daily from hotels and restaurants. Ashes and rubbish are collected once every 10 days.

Salt Lake City.—In the business district collections are made daily between 7 p.m. and 3 a.m. In the residence section collections are made once a week in the day time, the city being divided into six zones, having a collection in each zone on a stated day of the week.

Los Angeles.—The central and down-town districts receive collection three times a week. All other districts receive two collections a week.

London, Paris, Berlin, and Cologne.—Mixed refuse is collected daily.

Hamburg, Bremen, Frankfort, and Essen.—Mixed refuse is collected three times a week.

In the built-up sections of northern cities there should be at least three collections per week in summer and two in winter; in southern

cities the collections should be twice as often, or as local conditions may require.

Osborn and Fetherston recommend for Chicago that regular and systematic collection of garbage, ashes, and rubbish be made separately at daily or tri-weekly intervals, depending on the character of the districts served and the seasons of the year. This is a high standard for American cities and rarely found, but it is frequently maintained in Europe.

The frequency of garbage collection, whether it is or is not combined with rubbish, should depend on the season, and not on the density of population, as garbage becomes odorous as quickly in the suburbs as in the center of a city. If possible, garbage should be collected daily in hot weather, at least three times a week in spring and fall, and not less than twice a week in cold weather.

When refuse is left at the rear of premises for collection from alleys, it is not so important to have specified days and hours for the collection as when left in front of buildings on the sidewalks.

In warm weather, garbage should be collected at intervals of not more than two days, on account of its rapid decomposition. Ashes should be collected once or twice a week in winter, on account of their quantity, and once or twice a month in summer. In Milwaukee, throughout the summer of 1911, an attempt was made to collect no ashes from residences between June 15th and September 15th. It was found necessary, however, to make a collection during July, because of the many requests that were received. Rubbish should not remain uncollected longer than a month. Mixed refuse does not decompose nearly so quickly as garbage alone, but it accumulates more rapidly. In European cities it is collected from three to six times a week, in American cities only from one to three times a week, and therefore at less cost.

The difficulties often arising from infrequent collection, and the consequent and inevitable putrefaction, have caused many endeavors to be made to disinfect the garbage. It has been tried, particularly in Brussels, but the conclusion reached was that it affords only a temporary relief, and is far from justifying the requisite expenditure.

In reference to the disinfection of collection vehicles, the Public Health Service of the U. S. Government states as follows:

> "It is not suggested that any other solution except water should be used on wagons returning from the point of disposal; but, as a fly repellent, the wagons might be sprayed with a cresol solution. pine oil disinfectant, solution of gas-house waste, or kerosene oil. One of the western cities on the seacoast claims that thoroughly washing the wagons with sea water assists in the elimination of fly troubles."

Ordinances have been enacted in a number of cities, as in Michigan, Illinois, and Utah, regulating the collection and disposal of garbage. Recent decisions of several State Supreme Courts have held that the "property rights of individuals in garbage are subordinate to the general good, and that garbage disposal is subject to control by municipalities under the police power."

The City of Grand Rapids notified the proprietors of hotels and restaurants to discontinue the conveyance and disposal of their garbage to farms where it was fed to hogs and poultry, as it was in violation of a city ordinance. The Court has sustained the City.

The ordinance certainly was intended to be limited, in justice and for the common benefit, only in reference to the conveyance of garbage through the streets when it had become old enough to be offensive, and therefore to affect the public, in which case it should be controlled by the City and not by individuals. There could not be any reason for prohibiting the carting through the streets of garbage before decomposition had set in, i.e., only one or two days old, any more than prohibiting butcher or vegetable wagons from delivering goods.

The underlying object of such ordinances can only be a prevention of nuisance. This can always be accomplished by a sufficiently frequent collection of garbage and by keeping wagons and receptacles at all times thoroughly clean and covered.

2. Time Required for One Collection.—The time required to collect the refuse materials from each point of origin has also an important bearing on the economical arrangement of the collection service. It controls the number of collections which can be made during the working day, and thus determines the quantity of refuse which can be removed by each wagon. An increase in the time required to collect from each house will increase correspondingly the number of wagons required to serve a given population.

In April, 1911, a very complete record was kept of the work done by garbage collectors in Milwaukee. The trips of twenty-one collectors were observed, and data were secured showing the length of time spent by each one in harnessing his horse, going to the first place of collection, making the collections required to secure a full load, and delivering that load at the point of disposal. The records were kept for each wagon making one trip. The wagons ordinarily made two and sometimes three trips per day. Each had a capacity of 1.5 cu. yd.

The city is divided into small collection districts, their size, shape, and location being arranged so that the length of haul and difficulty of collection will allow the time for collecting two loads to approximate

an eight-hour day. The observations also covered districts in different sections of the city, where the conditions of service changed from small houses to hotels and apartments, thus affecting the number of places entered. These data are summarized in Table 53.

Table 53.—Collection Data, Milwaukee, Time Studies of Collectors' Work

Number of blocks covered on one trip	Number of places entered on one trip	Time, in Minutes, per Trip			Percentage of total time spent collecting	Average time, in minutes, to collect from one place
		Hauling	Collecting	Total		
3	58	225	80	305	39	1.38
5	49	167	60	227	26	1.22
2	32	174	75	249	30	2.34
2	45	60	48	108	44	1.07
3	39	150	70	220	32	1.79
4	45	88	128	216	59	2.85
4	24	110	115	225	51	4.80
8	106	100	133	233	57	1.25
4	38	210	106	316	34	2.79
2	15	100	70	170	41	4.67
6	8	66	55	121	45	6.87
4	9	36	44	80	55	4.90
1	6	92	32	124	26	5.33
3	58	119	56	175	32	0.97
4	15	136	64	200	32	12.80
6	18	75	105	180	58	5.85
5	90	115	185	300	62	2.06
3	59	89	155	244	64	2.63
1	26	151	115	266	43	4.43
5	13	120	85	205	41	6.54
6	45	50	100	150	67	2.22
6	32	160	90	250	36	2.81
Averages.	38	118	90	207	44	3.71

The most striking features of this table are the number of places which one collector can visit in one day and the length of time required at each house. It was found that, on the average, one collector could visit about 100 houses in an eight-hour day, and that the time required at each house was slightly more than two minutes. The individual results, however, are quite variable.

The importance of such information is emphasized by a statement of Arthur May, Cleansing Superintendent, London, as follows:

"It has been generally accepted that, with a chute [dump] within two miles of the Dusting District, a one-horse van with a capacity of 4 cu. yd. would, under normal conditions, make from 240 to 250 calls and collections each day of ten hours * * * In districts where dust-pans [house cans] are placed on the edge of the curb * * * it is quite possible to make as many as 500 collections in one day."

The London collector, therefore, is able to visit from two to five times as many houses per day as the Milwaukee collector. In other words, the work in London can be done by from one-half to one-third as many men per unit place of production of refuse. Mr. May states further that

"A large city like Manchester has over 7,000,000 weekly collections every year, and one minute's delay in each collection amounts in the year to a loss of 116,666 working hours for a horse and cart and one or two men."

It is chiefly the location of the can which determines the speed with which collectors can serve each house. Where the can is placed at the curb for the collector, as in London, Paris, Hamburg, and other European cities, it requires but a fraction of a minute to empty it into the wagon. The same operation in Milwaukee required about two minutes.

The type of receptable and the loading height of the wagon also affect the time of each collection.

Since these investigations were made in Milwaukee, similar observations have been made in Evanston by Mr. C. C. Saner, and in Chicago, Louisville, and elsewhere by Greeley. The results of these observations are given in Table 54. The capacity of the wagons used

TABLE 54.—COLLECTION DATA FROM SUNDRY CITIES.
SUMMARY OF TIME STUDIES FOR COLLECTION PER HOUSE

City	Number of observations	Average time per collection, in minutes *	Average number of houses per working day	Usual location of receptacle	Authority
Louisville, Ky.......	7	0.37	225	Curb	Greeley
Staten Island, N. Y..	2	0.91	....	Back door	Fetherston
Evanston, Ill........	9	1.21	79	Back door	Saner
Lake Forest, Ill.....	9	10.00	....	Back door	Greeley

* Time of hauling and dumping not included.

in Evanston was 1.5 cu. yd and in Chicago 5.0 cu. yd. In these two cities the time for one collection is less than in Milwaukee. Evanston is a residential suburb of Chicago, and Chicago has a much greater density of population. These factors had some effect in reducing the time of collection.

Time studies of garbage collection, made in Lake Forest, Ill., by Greeley, indicated an average time per collection of ten minutes. Lake Forest is a residential community in which the houses are on large lots. The observations were made at nine houses, the average distance from the street to the house being 630 ft.

Mr. C. G. Alfs, contractor for the collection and disposal of refuse at Decatur, Ill. (population 40,000), states that with a 5-mile haul to a dump, one 4-yd. wagon collecting mixed refuse can serve 100 houses in a nine-hour day. With delivery to a refuse incinerator, which is near the center of the city, each wagon serves from 200 to 250 houses per working day.

The investigations in Chicago were planned to indicate the variation in the time required for one collection of different kinds of refuse. Observations were made for mixed refuse, garbage, and for ashes and rubbish mixed. Table 55 gives the detailed results of these studies.

Table 55.—Collection Data, Chicago.
Time Studies of Collectors' Work

Material	Interval since last collection, in days	Number of places entered on one trip	Time to collect one load, in minutes	Average time to collect from one place, in minutes
Mixed refuse	7	63	115	1.8
	8	52	100	1.9
	4	51	80	1.6
Garbage	2	390	300	0.8
	3	535	345	0.6
	3	745	345	0.5
Rubbish and ashes	2	25	65	2.6
	8	112	135	1.2
	3	71	100	1.4
	7	24	85	3.5

Table 56 gives the results of time studies made in Washington, D. C.

TABLE 56.—COLLECTION DATA, WASHINGTON, D. C.
TIME STUDIES OF COLLECTORS' WORK

Material	No. of obser-vations	Number of places entered on one trip	Time, in Minutes, per Trip			Percentage of total time spent collecting	Average time, in minutes, to collect from one place *
			Collect-ing	Hauling	Total		
Garbage..	60	289	124	114	238	52.0	0.43
Ashes....	28	160	72	73	145	49.5	0.91
Rubbish..	44	160	125	153	278	45.2	1.74

* Time of hauling and dumping not included.

With more of such information it would be possible to get a fair figure for man-hour work and to make a proper estimate of the relative costs of collecting mixed and separated refuse. Similar investigations should be made more frequently along these lines.

3. Time of Collection.—The working time of a collector may be divided into the productive time, i.e., the time actually spent in collecting and emptying the house cans into the wagons, and the unproductive time, i.e., the time spent in driving the loaded wagon from the last point of collection to the point of transfer or final disposal. This division separates the time of collecting and the time of delivering the load.

The unproductive time should be kept as short as possible. To do this under ordinary conditions requires that the wagon be as large as possible, so that it can make the least number of trips to the point of unloading. If it were possible to handle a wagon of so large a capacity that the time required to load it would leave time to make only one trip per day, then the most economical use of the wagon would result. Local conditions, however, generally do not permit this. In Chicago, for instance, it is found that there are districts where a working day is too short to fill completely a 4-yd. wagon with garbage for a single trip to the disposal works or transfer station. Obviously, therefore, in a large city, wagons of different sizes will be required to meet most economically the variations in the different districts. New York City has been using a 5-ton auto-truck, Fig. 14, for hauling garbage and ashes, as the hauls are much shorter than in Chicago. The standard New York garbage cart, however, with sideboards, Fig. 15, holds only 2.0 cu. yd., and the ash wagon 3.0 cu. yd. The large wagon, to shorten the unproductive time, therefore, is a striking departure from past practice. Mr. E. D. Very, of New York, speaks enthusiastically of the expected economies therefrom.

Fig. 14.—Five-ton Mack Truck, New York City.

Fig. 15.—Standard New York Garbage Cart.

The percentage of the total working time of a collector which is used productively has been found to be:

For Chicago	50.0%
" Milwaukee	45.0%
" Evanston	86.0%
" Washington	45.2%
" Louisville	27.0%

4. Length of Haul.—If all refuse materials from a given area are taken to one point of disposal, the length of haul will be about double that which would be required if two points of disposal were available in the same area. This fact frequently indicates the most economical plan of collection, and shows the important relation between collection and method of disposal.

For example: In Milwaukee the most available site for a reduction plant was at Mequon, about 7 miles north of the city. On the other hand, a very central location was available for an incinerator, with suitable locations convenient for future plants. The cost analyses showed that the incineration of mixed refuse at a central incinerator would be cheaper than the reduction of the garbage, the burning of rubbish, and the dumping of ashes. The balance in favor of the incinerator method of final disposal of all refuse was due to the shorter average haul. In Chicago, on the other hand, a very central location was available for reduction works, and this method of disposal, with separate collection, proved to be cheaper than burning mixed refuse, even at a number of plants at various locations throughout the city.

In a city of 100,000 people, producing 50 tons of garbage per day, a change in the length of haul sufficient to increase the cost of collection 20 cents per ton is equivalent to a capital sum of about $60,000. This sum will generally be more than the difference between the greater cost of building two smaller disposal stations and the smaller cost of one larger plant.

In cities covering large areas, the length of team haul must be reduced by having transfer stations from which the refuse can be taken by train, barge, motor truck, or trolley to the point of final disposal. This subject is discussed fully in Chapter IV.

5. Speed Rate.—The cost of team haul will vary with the speed of travel and the tonnage hauled. Mr. George A. Zinn, in a paper * entitled " Chicago's Waterways and their Relation to Transportation," gives the price of team haul as 50 cents per ton-mile. This subject was investigated carefully in Chicago during 1913, resulting in an allowance of 3 miles per hour for the average speed of travel.

* Presented before the Western Society of Engineers in April, 1912.

In Milwaukee, during the summer of 1911, this was found to average 3.6 miles per hour. It was also ascertained in Chicago that teams hauling ice could make an average rate of 3.0 miles per hour loaded, and the drivers were instructed not to exceed this rate greatly when their wagons were empty. The actual rate of travel of garbage, ash, and rubbish wagons in Chicago was found by the Civil Service Commission to be 2.7 miles per hour. A speed of 3.0 miles per hour, however, should be secured under reasonably favorable conditions of streets and of operation.

For a standard rate of travel, the cost of team haul per ton-mile will vary with the rate of wages paid the driver for his time and team, and can easily be computed for the various weights of refuse hauled.

In Chicago, the weight of the average load of garbage hauled is 2.0 tons, and of ashes and rubbish 2.5 tons. Where rubbish is collected separately, the tonnage that can be handled in one wagon is much smaller but the yardage is greater. In Columbus, and in Buffalo, 8-yd. wagons have been used successfully for hauling rubbish. The net weight of rubbish hauled in such a wagon averages 0.8 ton. The cost of haul per ton-mile for rubbish, therefore, is much larger than for garbage and ashes. Under these conditions, and with wages at 75 cents per hour the unit costs of team haul may be averaged as follows:

	Cost of Team Haul per Ton-mile. (Round Trip)
Garbage	$0.25
Ashes	0.20
Rubbish	0.62
Mixed refuse	0.20

Of course, these unit figures require adjustment to local conditions after sufficient investigation. The cost of hauling a 5-ton load by motor truck is shown in Chapter V to be about $0.16 per ton-mile (round trip).

The cost of collecting and handling mixed refuse in Toronto is approximately $1.35 per ton-mile.

6. Quantity per House.—The cost of collection depends also on the quantity of refuse produced per capita, or per house, and, therefore, on the time required to get a full load. For a given frequency of collection, the collector will find a smaller accumulation in the house can when smaller quantities are produced per capita, and the time of getting a load will be correspondingly lengthened. When larger quantities are collected at each house, a wagon of given size will be more quickly filled, and will not serve as many houses on one trip.

This condition is particularly evident when making comparisons of refuse collection in European and American cities. For European conditions, with a smaller per capita production, the mixed refuse of 100,000 people can be removed by about 15 wagons. In American cities, about 30 wagons are required for a similar service. These figures are only approximate, yet they show that the quantity of refuse produced per inhabitant and per house must be considered in an analysis of the collection work.

7. Computations for Collection Service.—The relative effect of the foregoing details on the collection service can be seen best by representing them in algebraic form. The following letters represent the various factors entering into the computations:

W = Number of collection wagons;
V = Capacity of one wagon, in cubic feet;
F = Interval between collections, in days;
T = Time required to collect from one house, expressed as parts of an hour;
C = The percentage of working time spent by the collectors in the actual time of collecting, as distinguished from hauling to and from the point of disposal;
D = Length of working day, in hours;
S = Number of trips to point of disposal per wagon per day;
P = Total population served;
N = Average number of people per house;
R = Daily quantity of refuse per capita, in cubic feet;
g = Daily quantity of garbage per capita, in cubic feet;
a = Daily quantity of ashes per capita, in cubic feet;
r = Daily quantity of rubbish per capita, in cubic feet.

These factors are embodied in the following expressions:

$$S = \frac{D \times C}{T} \times F \times N \times R \times \frac{1}{V}, \qquad (a)$$

$$W = \frac{P \times R}{S \times V} \qquad (b)$$

Equation (a) shows the number of trips to the point of disposal, or transfer, for each collection wagon per day, in terms of the productive working time, the time to collect from one house, the frequency of collections, the per capita production of refuse, and the capacity of each wagon. It shows that the number of trips per day which can be made will increase with the productive working time and the per capita production of refuse, but will decrease as the time required to visit one house increases and the size of the wagons becomes larger.

Equation (*b*) shows the total number of wagons required, in terms of the total quantity of refuse produced for a given population, the number of trips per wagon per day, as computed from Equation (*a*), and the capacity of each wagon. The number of wagons required will be greater for greater quantities of refuse, and will be less for larger wagons making the same number of trips per day to the point of disposal. These two expressions serve to bring out the relative importance of the various factors in the collection service. They should not necessarily be considered as formulæ giving definite results. Being purely analytical, they should serve merely as a general guide in solving problems.

This method of computation for the arrangement of refuse collection was used in Chicago in the report of 1914 by Osborn, Fetherston, and Greeley. The following is a typical computation for the 25th Ward of that city:

Computation for Number of Teams in Ward 25, Chicago

General Data.

Collection Frequency:

Ashes and Rubbish—Winter—twice a week.
Summer—once a week.
Garbage—Winter and Summer—three times a week.
Mixed Refuse—Winter and Summer—twice a week.

Capacity of Wagons:

Garbage, 4.0 cu. ya. = 108 cu. ft.
Ashes and Rubbish, 5.0 cu. yd. = 135 cu. ft.
Mixed Refuse, 5.0 cu. yd. = 135 cu. ft.

Time for 1 Collection = T in Equation (*a*):

Garbage, 1 minute.
Ashes and Rubbish, 2 minutes.
Mixed refuse, 2.5 minutes.

Production, in cubic feet per 1000 population per day:

	Winter	Summer	Average
Garbage	10.	23	15
Ashes and Rubbish	95.	57	76
Mixed Refuse	..	..	100

Number of people per collection = 10.
Length of working day = 8 hours.
Rate of travel in haul = 3.0 miles per hour.

Special data for Ward 25:

Length of average haul = 4 miles.

The method of computation is as follows:

I. Trips per day

$$=\frac{(\text{Length of working day, in minutes}-\text{time spent hauling, in minutes})}{(\text{Time for 1 collection, in minutes})}$$

$$\times\frac{(\text{Quantity per collection})}{(\text{Capacity of wagon})}.$$

II. No. of Wagons per 100,000 $=\dfrac{(\text{Quantity per capita})\times 100{,}000}{(\text{Trips per day})\times(\text{capacity of wagon})}$.

Substituting in Equations (a) and (b):

Garbage,

Summer:

$$S=\frac{\left(8\times 60-S\times 4\times 2\times\frac{60}{3.0}\right)}{1.0}\times\frac{23}{1000}\times 10\times 2\times\frac{1}{108}=1.21 \text{ trips per day,}$$

$$W=\frac{\frac{23}{1000}\times 100{,}000}{1.21\times 108}=17.5 \text{ wagons per 100,000 population.}$$

Winter:

$$S=\frac{(480-160S)}{1.0}\times\frac{10}{1000}\times 10\times 2\times\frac{1}{108}=0.69 \text{ trip per day,}$$

$$W=\frac{\frac{10}{1000}\times 100{,}000}{0.69\times 108}=13.4 \text{ wagons per 100,000 population.}$$

Average:

$$S=\frac{(480-160S)}{1.0}\times\frac{15}{1000}\times 10\times 2\times\frac{1}{108}=0.92 \text{ trip per day,}$$

$$W=\frac{\frac{15}{1000}\times 100{,}000}{0.92\times 108}=15.1 \text{ wagons per 100,000 population.}$$

Ashes and Rubbish,

Summer:

$$S=\frac{(480-160S)}{2.0}\times\frac{57}{1000}\times 10\times 6\times\frac{1}{135}=2.01 \text{ trips per day,}$$

$$W=\frac{\frac{57}{1000}\times 100{,}000}{2.01\times 135}=21.0 \text{ wagons per 100,000 population.}$$

Winter:

$$S=\frac{(480-160S)}{2.0}\times\frac{95}{1000}\times10\times3\times\frac{1}{135}=1.88 \text{ trips per day,}$$

$$W=\frac{\frac{95}{1000}\times100{,}000}{1.88\times135}=37.4 \text{ wagons per } 100{,}000 \text{ population.}$$

Average:

$$S=\frac{(480-160S)}{2.0}\times\frac{76}{1000}\times10\times4\times\frac{1}{135}=1.94 \text{ trips per day,}$$

$$W=\frac{\frac{76}{1000}\times100{,}000}{1.94\times135}=29.0 \text{ wagons per } 100{,}000 \text{ population.}$$

Mixed Refuse,

Average:

$$S=\frac{(480-160S)}{2.5}\times\frac{100}{1000}\times10\times3\times\frac{1}{135}=1.76 \text{ trips per day,}$$

$$W=\frac{\frac{100}{1000}\times100{,}000}{1.76\times135}=42.2 \text{ wagons per } 100{,}000 \text{ population.}$$

Summary:	Wagons per 100,000 population:		
	Winter	Summer	Average
Garbage	13.4	17.5	15.1
Ashes and Rubbish	37.4	21.0	29.0
Mixed	....	....	42.2

The foregoing computations were simplified by using the diagrams, Figs. 16, 17, and 18. The method of analysis described can be extended and used in greater detail, as was done by Hering and Gregory for Dayton, Ohio. Fig. 19 is a diagram used in garbage collection computations.

Table 57 shows the actual number of wagons, per 100,000 population used in the various wards in Chicago for 1912. The number required under assumed conditions of better service is shown in Table 58. The application of this method of computation to ascertain the service in European and American cities for different classes of refuse materials is shown in Table 59.

F.—EQUIPMENT

In the foregoing analysis, the conditions affecting the choice of the wagons for the collection service were not considered. Some of the more important requirements, which not only affect the cost of the collection but also the sanitary efficiency, are as follows:

1. Size of Wagons.—Theoretically, as just stated, a refuse wagon should be of such a size that the time required to fill it leaves just sufficient time in one working day for one trip to the point of disposal.

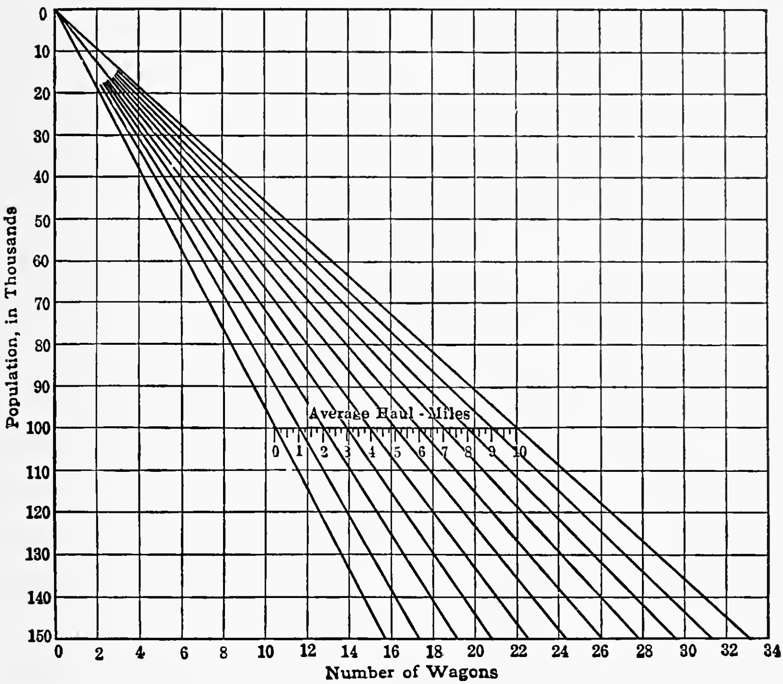


Fig. 16.—Diagram for Estimating Number of Wagons Required to Collect Garbage.

This condition reduces the unproductive time. Further, a large wagon generally requires for its operation a more intelligent collector, and this promotes the essential co-operation between the householder and the collection department.

Practically, the best wagon size for each locality can be determined only after a consideration of a number of conditions. There is the area and the population of a district; the relative time spent

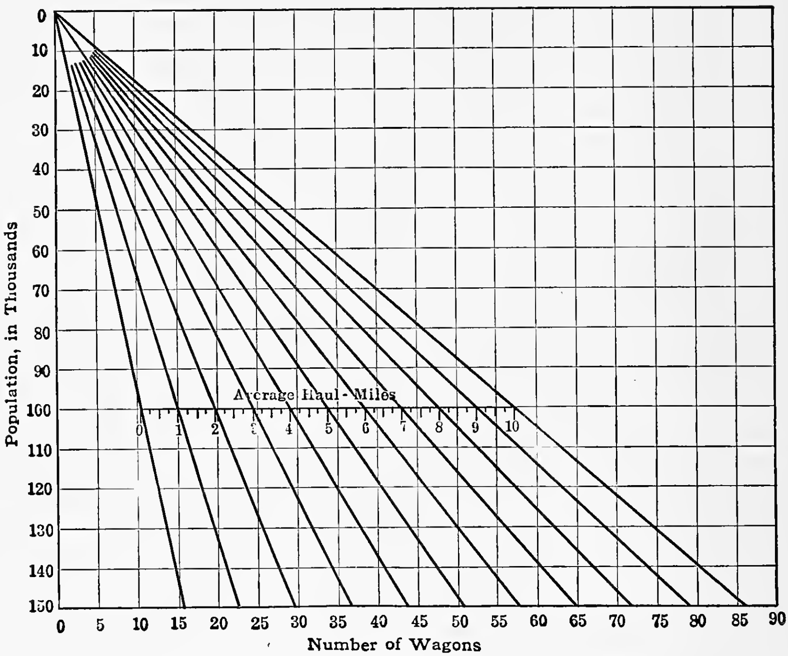


FIG. 17.—Diagram for Estimating Number of Wagons Required to Collect Ashes and Rubbish.

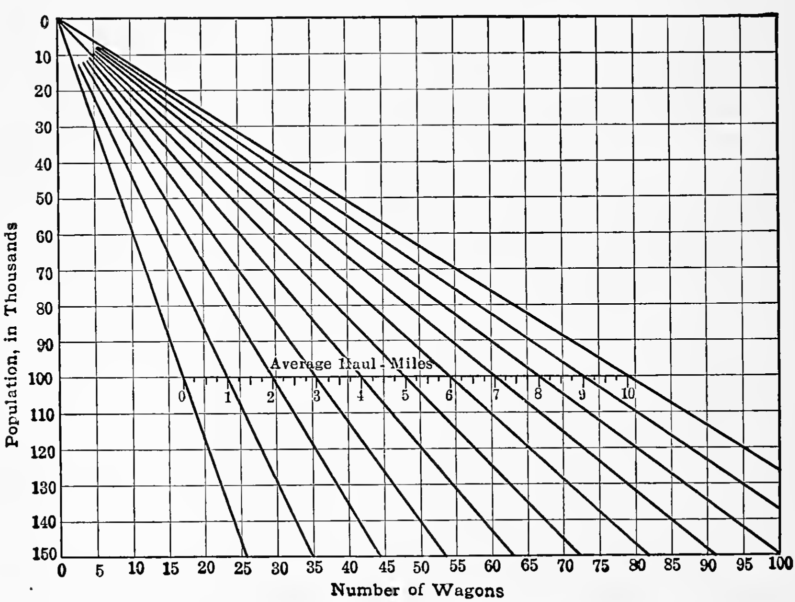


FIG. 18.—Diagram for Estimating Number of Wagons Required to Collect Mixed Refuse.

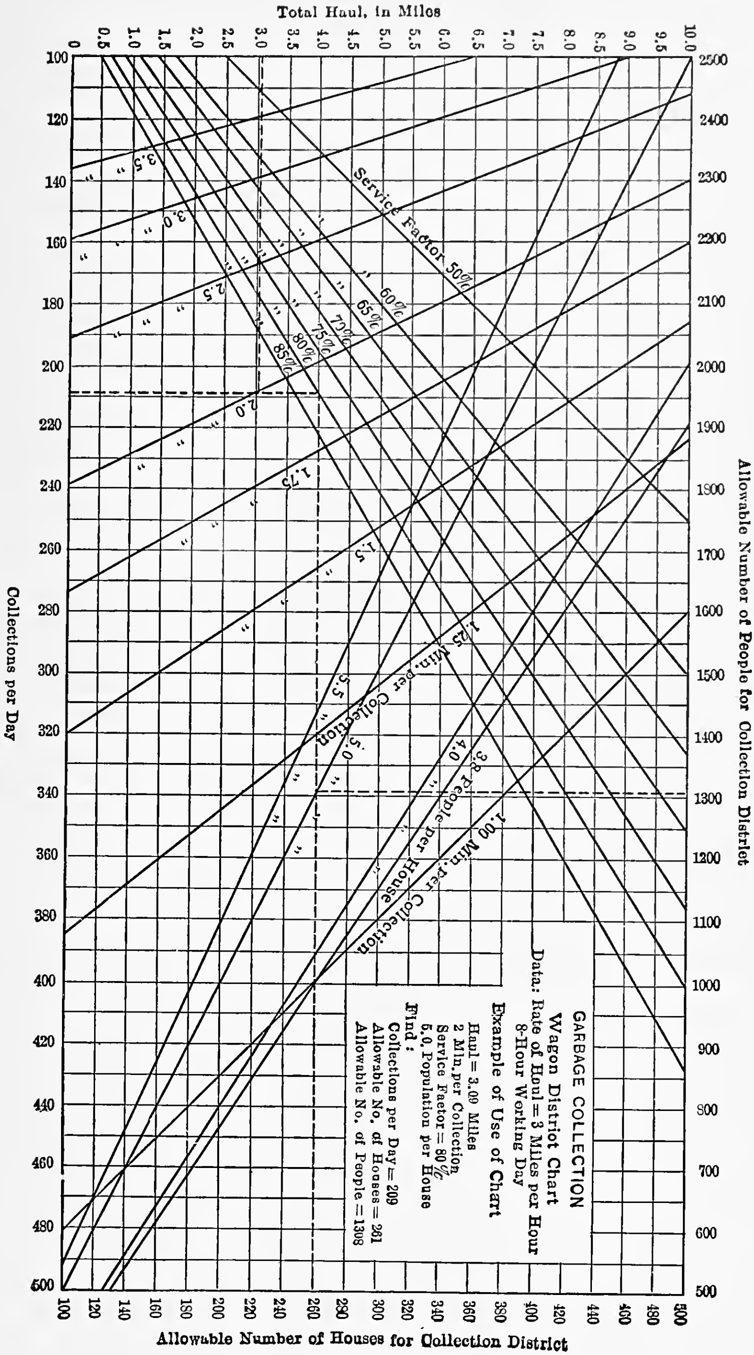


Fig. 19.—Wagon District Chart.

TABLE 57.—COLLECTION EQUIPMENT AND SERVICE IN CHICAGO, 1912

Ward	Garbage				Ashes and Rubbish			
	Wagons per 100,000 population	Number of collections per week		Average number of miles hauled per trip	Wagons per 100,000 Population	Number of collections per week		Average number of miles hauled per trip
		Winter	Summer			Winter	Summer	
1	6	6	6	4.0	33	6	6	4
2	11	6	6	2.7	25	1–2	1	4.2
3	9	1	3	3.7	25	1	1	3.8
4	9	2	2	2.0	16	2	3	3.5
5	6	2	3	2.0	11	2	2	2.0
6	7	2	3	5.5	16	2	1	4.5
7	7	2–3	3	7.0	20	2	2	4.5
8	No separation				12	2	3–2	1.7
9	"	"			16	1	1	2.0
10	6	2	6	3.3	15	2–3	3	2.1
11	5	6	6	3.0	15	6	6	2.0
12	4	2–3	3	4.5	8	3	2	2.0
13	11	2	2	4.1	20	1–2	1	3.5
14	8	2	2–3	3.2	20	2	2	3.9
15	9	2	2	3.5	16	1	1	3.3
16	6	3–6	3–6	2.5	14	2–3	2–3	3.4
17	6	6	6	1.0	14	1	1	4.5
18	10	2–3	6	2.2	18	2	3	2.5
19	6	2–3	4	2.5	22	2–3	2	2.5
20	9	3	4–5	2.8	20	2–3	3	2.5
21	8	3	6	1.6	40	3	3	4.8
22	7	2	3	1.0	24	2	3	3.6
23	11	2	2	2.6	25	1	1	3.1
24	10	2	2–3	1.2	20	3	2	2.0
25	12	2	2	4.5	16	2	2	3.5
26	9	2	2	3.5	18	1	1	1.5
27	6	1	2	3.3	10	3	2–3	2.0
28	10	2	2	1.5	16	3	2	1.8
29	4	2	2	4.0	11	2	2	1.5
30	8	3	3	3.0	16	1–2	1	2.1
31	11	1	2	3.5	16	1–2	1	3.5
32	9	1–2	2	6.0	18	2	2	1.3
33	9	2	2	5.0	12	1	1	4.0
34	8	1–2	2	5.5	14	2–3	2	1.2
35	9	1	2	5.0	14	1–2	1	4.0
Aver..	8	...	...	...	18	...	...	...

in collecting and in delivering; the fact that a 6-ton wagon requires no more labor than a 4-ton wagon, and less time is used for the larger wagon at each end of its journey. Finally, the size is influenced by the kind of material to be collected.

Table 58.—Number of Collection Wagons Necessary to Give Good Service

Chicago Refuse Disposal, March, 1914

District	Number of Wagons per 100,000 Population Necessary for Collect.ng:			
	Garbage	Ashes	Rubbish	Ashes and rubbish
Wentworth and 39th Sts.	12.5	18.5	11.9	21.6
Kedzie Ave. and Canal	12.3	14.5	11.9	18.2
State and 64th Sts.	12.5	18.0	12.1	17.8
Mayfair	10.9	12.2	10.9	12.4
Western and 64th Sts.	12.6	18.2	12.4	17.5
Lumber and 18th Sts.	12.4	18.7	12.3	19.4
Austin and Claremont	12.3	17.3	12.1	18.0
Chicago Ave.	12.2	17.0	12.0	19.2
Diversey Blvd. and N. Br.	12.3	17.4	10.5	18.2
Irving Park and Rockwell	13.0	20.2	12.8	21.0
Cortland and Crawford	13.0	21.0	12.9	22.1
Carroll and Crawford	12.4	17.0	12.2	19.3
Stony Island and 95th	12.3	17.8	12.1	21.3
Reduction Works	12.3	17.9	12.1	21.0
Totals	173.0	245.7	168.2	267.0
Averages	12.3	17.5	12.0	19.1

An advantageous capacity for rubbish wagons appears to be from 8 to 10 cu. yd. In large cities with congested populations, the best capacity for garbage wagons and for ash wagons is about 4.5 cu. yd., and for mixed collection about 5 to 6 cu. yd. In smaller and residential towns, the working day is not long enough to fill large wagons. Investigations in Winnetka and Lake Forest, Ill., indicate that wagons of 1.5 cu. yd. capacity are large enough. In large cities, on account of the greater variety of conditions, the equipment should include wagons of different capacities.

Fig. 20 shows a box attached to an ash wagon; it is of sufficient

size to hold the winter production of garbage. The figure shows such a wagon as used in Winnetka, Ill.

TABLE 59.—EXAMPLES OF APPLICATION OF THE METHOD OF COMPUTATION

City	Population served	Actual number of wagons in service	Capacity of wagons in cubic yards	Interval between collections, in days	Percentage of assumed time spent in collecting	Assumed time required per house, in hours	Number of trips per wagon per day	Number of Wagons per 100,000 Population: Actual	Number of Wagons per 100,000 Population: Computed
	P	W	$\frac{V}{27}$	F	C	T	S		
American Cities—Separate Collection									
Garbage									
Milwaukee..	375,000	95	1.5	8.0	0.45	$\frac{1}{20}$	2.14	25	23
Columbus...	181,000	20	2.5	4.5	0.65	$\frac{1}{40}$	2.08	11	14
Rochester...	225,000	30	3.3	3.0	0.70	$\frac{1}{60}$	1.68	13	13
Ashes and Rubbish									
Columbus...	181,000	40	3.5	10.0	0.50	$\frac{1}{20}$	5.92	22	22
Rochester...	225,000	50	4.0	6.0	0.60	$\frac{1}{25}$	4.67	22	24
European Cities—Mixed Collection									
Hamburg...	1,000,000	90	5.0	2	0.75	$\frac{1}{90}$	2.41	9	12
Frankfort...	920,000	60	2.5	2.5	0.65	$\frac{1}{60}$	3.47	14	17

Assumptions: (See page 123) $D = 8$ hours; $R = 0.04$ cu. ft. for European cities; $g = 0.02$ cu. ft. for American cities; $a = 0.07$ cu. ft. for American cities; $r = 0.05$ cu. ft. for American cities.

2. Loading Height.—The loading height of a general refuse wagon should be such that the workmen can easily turn the contents of the can into it. If only one man operates the wagon, the height should be not more than 6 ft., and preferably not more than 5 ft., from the ground. If step-boards are placed at the rear and on the sides between the wheels, a somewhat higher wagon may be loaded conveniently.

The trucks for the removal of dead horses, etc., should be hung low, in order to avoid an excessive lift.

The greatest loading height of a rubbish wagon is different. As

rubbish is a lighter and cleaner material, the collector can pile it to a greater height. The rubbish wagons in Buffalo and New York are

FIG. 20.—Ash Wagon, Winnetka, Ill., with Garbage Box Attached.

FIG. 21.—New York Rubbish Wagon.

loaded to a height of more than 8 ft. Fig. 21 shows a rubbish wagon used in New York City.

3. Wheel Base.—In undeveloped districts, where there are many rough roads and narrow alleys, and where short turns are required, a

long wheel base is objectionable. An attempt to increase the capacity of a wagon tends to increase the wheel base, which makes it clumsy. For some districts, therefore, it will be desirable to have special wagons, made with short wheel bases, or to use two-wheeled carts instead.

4. Covering.—For several reasons, refuse wagons require covering. Those used for collecting ashes and rubbish or mixed refuse should be covered in order to prevent dust and loose papers from being blown into the street. Those used for garbage should be covered so as to prevent a nuisance to both sight and smell. Fig. 22 shows a covered wagon used in Newark.

Fig. 22.—Covered Wagon, Newark, N. J.

Fig. 23 shows a garbage cart, used on Staten Island, N. Y., covered with canvas. In Cologne, Germany, a wagon for mixed refuse is fitted with a fixed cover, the refuse being loaded through doors hinged on the sides and at the rear. Fig. 24 shows a garbage wagon, with hinged covers, used in Chicago. Similar vehicles are used in Cleveland and Milwaukee.

A large garbage wagon is used in Minneapolis; it is covered with canvas, and has a capacity of 100 cu. ft., the body being removable for transportation by train.

The hinged type of cover or lid, used in Chicago and elsewhere, often becomes bent or broken, and when the wagon is filled, a box, barrel, or other large piece of refuse, often prevents the lid from closing. Garbage juices tend to adhere to the hinges, and thus it is difficult to keep the wagon clean. When it is empty and is passing over rough pavements, the noise made by the rattling of the loose

FIG. 23.—Garbage Cart, with Canvas Cover, Staten Island, N. Y.

FIG. 24.—Garbage Wagon, with Hinged Covers, Chicago, Ill.

covers is objectionable. The tight-fitting covers used abroad do away with these troubles. Fig. 25 shows a type of wagon with closed cover used in Zurich, Switzerland.

Wagons should be built with the top about a foot above the loading height. The flat canvas cover has the advantage of cheapness and simplicity, but it becomes soiled and torn, and cannot be kept in place during the loading. An arched canvas cover, as in Newark, appears to be preferable. A careful man will keep his wagon covered as much as possible while collections are being made.

Newark has about 50 ash wagons, each having four covers, one sliding over the other. This arrangement makes it possible to leave not more than one-quarter of the top temporarily open while loading,

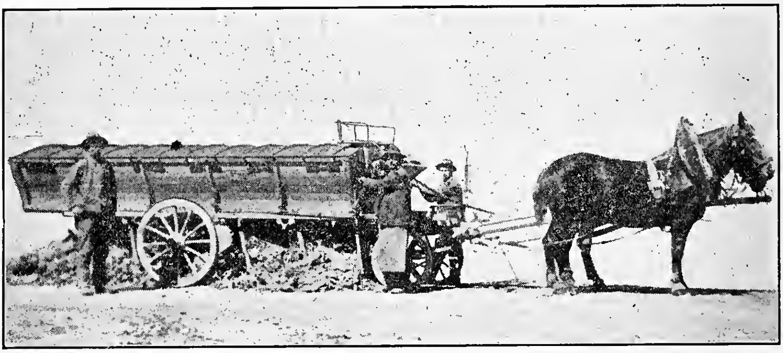


Fig. 25.—Wagon with Closed Cover, Zurich, Switzerland.

and greatly prevents dust from blowing to the sidewalk. A wagon of this type is shown in Fig. 22.

5. Wagon Bodies.—Wagon bodies should preferably be made of steel, with smooth interior surfaces and round edges and corners, for easy washing. Ribs and stiffeners should be placed on the outside. The running gears are of wood or steel, of standard construction. The wagons should be well painted on the outside, and kept in a clean and proper condition.

In addition to the wagon, the full equipment requires a small bucket, a shovel, and a broom. The necessity for these attachments depends on the nature of the house treatment. With standard cans, well kept, and generally used by the householders, this wagon equipment is not required. In cold climates a pick is sometimes needed to break frozen garbage. A small roller truck is frequently used for carrying heavy cans.

Wagons are sometimes divided into compartments, each covered with a lid. One object in having such compartments is to expose to the open air as small an area as practicable; another is to afford opportunity for the simultaneous collection of different kinds of refuse, which are to be kept and disposed of separately.

Fig. 26 shows a motor-drawn wagon, with compartments, having a capacity of 25 cu. yd., as used in New York City.

Some bodies have movable partitions, as in Salt Lake City, so that the garbage may be kept separated from the other refuse.

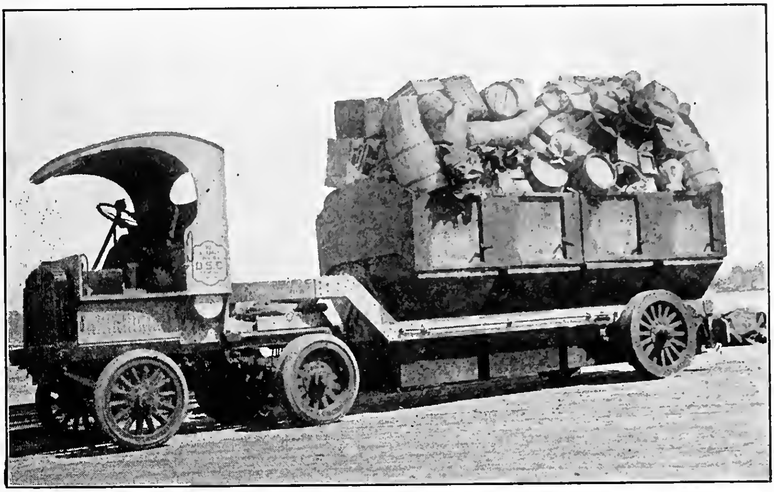


FIG. 26.—Motor-drawn Wagon, with Compartments, New York City. Capacity, 25 Cubic Yards.

6. Dumping.—The loaded wagon must be dumped with as little loss of time as possible. The method of dumping depends partly on the method of final disposal. Where the refuse is taken to dumps, bottom-dumping wagons are most serviceable. They are suitable for ashes, rubbish, or mixed refuse. Bottom-dumping wagons, of 4 cu. yd. capacity, were tried in Milwaukee for the collection of garbage; but, as it was impossible to keep them water-tight in wet summer weather, they were objectionable. The distance from the ground to the bottom of the wagon is limited to a certain maximum, sufficient to give clearance to the bottom when opened; this limit reduces the available capacity.

The rubbish wagons used in Winnetka, Ill., and Dallas, Tex., are shown in Figs. 27 and 28. The Milwaukee (Studebaker) dumping

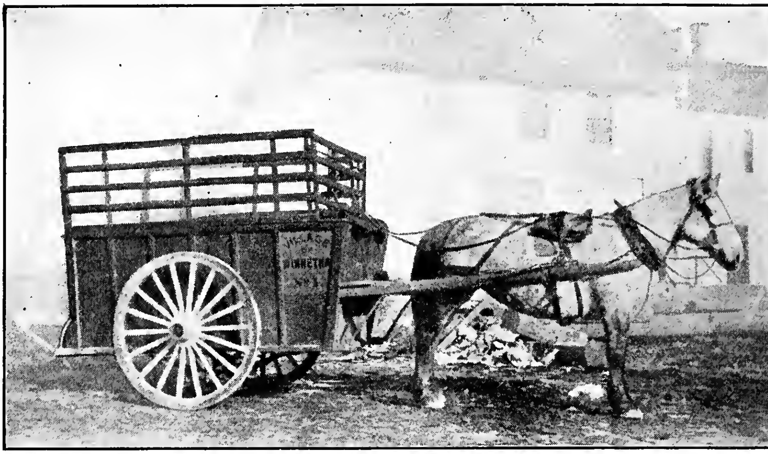


Fig. 27.—Rubbish Wagon, Winnetka, Ill.

Fig. 28.—Ten-yard Rubbish Wagon, Dallas, Tex.

wagon—capacity, 4 cu. yd.—is shown in Fig. 29. Fig. 30 shows another Studebaker horse-drawn garbage collection wagon with metal covers and complete dumping apparatus.

Fig. 29.—Garbage Wagon, Milwaukee, Wis.

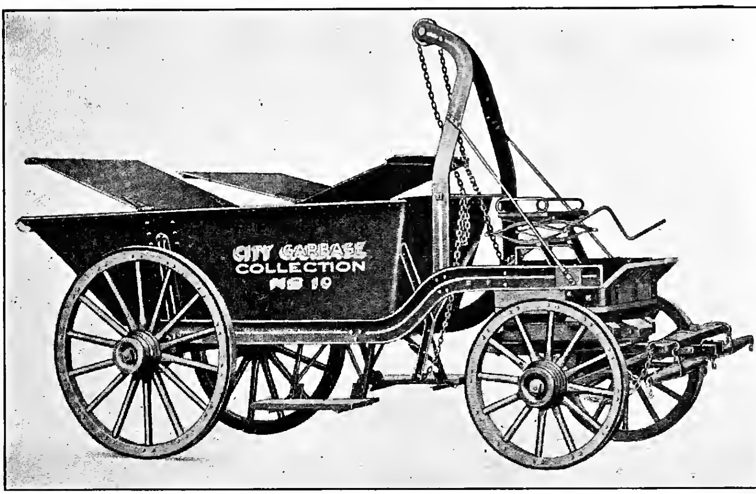


Fig. 30.—Two-yard, Studebaker, Garbage Wagon with Metal Covers, and Dumping Apparatus.

In most wagons for refuse collection in Europe the body is set on hinges at the rear axle, and is dumped by raising the forward end.

This permits a large wagon body to be used, and facilitates dumping anywhere with reasonable speed. The front of the wagon body can be lifted by a crane at the unloading station, as is the case also at Columbus, Ohio, or by a hand-turned gear.

In Lakewood, Ohio, the garbage is collected in large cans placed on low-hung, horse-drawn vehicles. At the transfer station these cans are transferred to 6-ton motor trucks, each carrying six cans. The motor truck and the horse-drawn vehicle, both built by the Tiffin Wagon Company, are shown in Fig. 31.

A $6\frac{1}{2}$-yd. rubbish wagon, with a hand-power hoist, also built by the Tiffin Company, used in East Cleveland, Ohio, is shown by Fig. 32.

The garbage wagon built by the Holzbog Company is shown by Fig. 33. The body has tight covers, and the interior contains no niches or corners where filth might be retained. The method of dumping is evident from the illustration. The wagon is made in two sizes, having capacities of 37 and 54 cu. ft., for one horse or two.

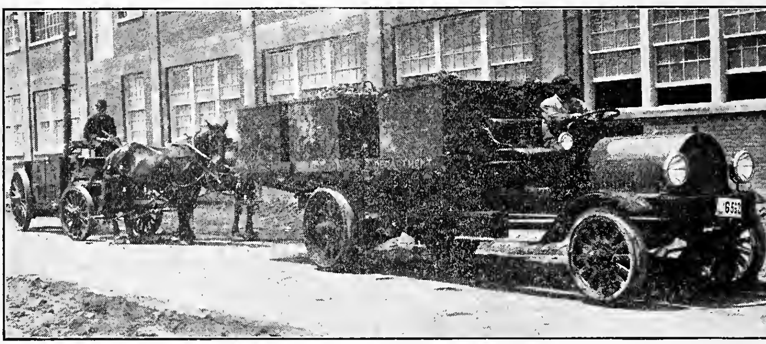


Fig. 31.—Six-ton Motor Truck Carrying Six Garbage Containers; and Horse-drawn Collection Wagon Carrying One Garbage Container, Lakewood, Ohio.

Wagons are also built with removable steel bodies which can be lifted from the truck by a crane and placed on freight cars or scows for removal to the disposal works. The removable body is often lifted directly into the disposal plant and, after dumping, is returned to the wagon frame. This method of unloading is used at Minneapolis, Chicago, and Milwaukee, at Zurich, Frankfort, and Hamburg, in Europe, and at other places. The unloading requires considerable time, depending on the length of the crane. At the Milwaukee incinerator, it is possible to unload by this method from 20 to 25 wagons per hour per crane. With two cranes working, the capacity of the

plant for unloading is about 40 wagons per hour, which is just sufficient to keep ahead of them as they arrive.

Fig. 32.—Special $6\frac{1}{2}$-yard Rubbish Wagon with Hand-power Hoist, East Cleveland, Ohio.

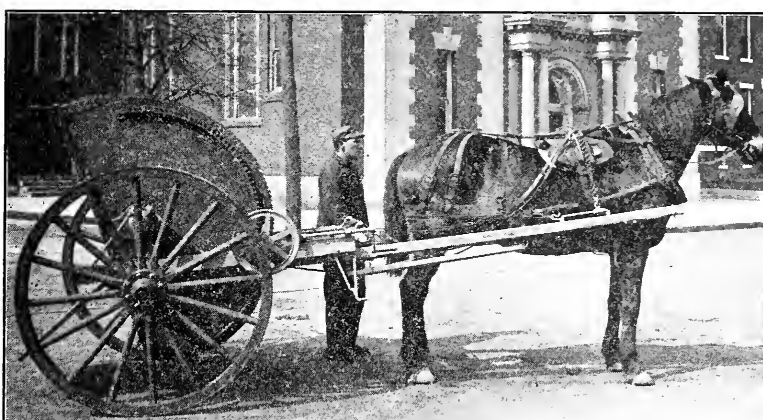


Fig. 33.—Holzbog Garbage Wagon.

Ash and rubbish wagons in Chicago are built with fixed wooden bodies, having a capacity of 5 cu. yd. When unloading at the dump,

the refuse must be shoveled out at the rear end. The average time required for unloading one wagon is about twenty-five minutes.

In order to shorten the time of unloading at the refuse disposal works, and to make the wagon independent of the unloading machinery, dumping or storage pits may be provided. Such pits are utilized at the mixed refuse incinerators in Paterson, Clifton, Havana, Savannah, and San Francisco. The wagons dump directly into the pits, and the refuse is lifted from them by grab-buckets, and conveyed to the furnaces.

At some other places, large buckets are set into cellar pits below the roadway level, as in Brooklyn, instead of using one large dumping pit. Bottom-dumping wagons drive over the buckets and discharge into them. The buckets are subsequently lifted by cranes and taken to the furnace. At Milwaukee, four such buckets are provided. At Greenock, Scotland, there are two pits each large enough to hold one special bucket. There are 100 of these buckets at the plant. An empty one is dropped into a pit, and, when filled, is lifted by a crane and placed on a storage floor above the furnace. The refuse is stored in these buckets until burned.

7. Cleaning Wagons.—The separate collection of garbage, as practiced mostly in America, demands a frequent and thorough cleaning of the wagons. Under European conditions, with mixed refuse, the wagons are ordinarily washed after each day's work. In Milwaukee, two washings a week, with a hose and a broom, were not sufficient to prevent the garbage wagons from creating a nuisance in hot weather. In Chicago, the garbage wagons are fitted with removable bodies, which are cleaned by dipping them into a large tank of hot water. This is done just after the wagon body has been unloaded by the crane at the reduction works. When the washing is not done regularly, offensive odors result. Frequent re-painting is also desirable.

The European refuse wagon is ordinarily arranged to dump by tipping it over the rear axle. When it is in this position, it can be easily flushed and cleaned at the yard with a hose. This method seems to be preferable to most others. The washing at Milwaukee required a man to get into the wagon and sweep the water out with a broom. An estimate of the cost of washing per wagon was as follows:

100 wagons can be washed per day by one man, at $2.00.......	$0.02
330 gal. of water, at 6 cents per 1000 gal....................	0.02
Fixed and overhead charges, driver's time, etc...............	0.01
Total cost per wagon........................	$0.05

The design of a wagon, particularly one to be used for the collection of garbage alone, should include arrangements for easy cleaning,

preferably by water from a hose under pressure. As the odor from garbage results from putrefaction, the leavings in the unwashed wagons are the chief cause of the trouble.

8. Horses.—With reference to the care of horses used for refuse collection, we can do no better than refer to a pamphlet prepared by the Department of Street Cleaning of New York City, when Mr. Fetherston was Commissioner, defining the duties and responsibilities of the veterinarians of the department and systematizing the medical care of the stock. This pamphlet was prepared and liberally distributed, advising how to prevent sickness of horses, how to determine sickness, and what to do for it. It also outlined the proper manner in which the stock was to be watered and fed.

The result in the Department was very beneficial, as it greatly reduced the sick and death rates and increased the amount of work that could be done by the horses. Every horse is well cared for, and receives a new shoe on each foot at least once a month. Throughout the year the feet are equipped with hoof protectors, when pads are not used. In the winter the horses are provided with heavy woolen blankets.

It is still the prevailing practice to use horses for collecting refuse at the houses, because of its economy. The many stops required result in a very irregular power demand, and an uneconomical service for motor vehicles. Horse-drawn vehicles, therefore, are preferable, especially for a haul of less than one or two miles. It may apparently be a long time before horse power will be displaced by electric power, or even gasoline power, when the collection is from small areas or scattered buildings and for light loads. Data regarding the decrease in the number of horses in cities will be found in Chapter XIV.

9. Motor Trucks.—The rapid increase in the use of large gasoline trucks in the place of horse-drawn trucks has been due to the fact that the larger the tonnage of the vehicle, the less will be the mileage of haul per ton, and consequently the cost of haulage per ton-mile. It is practicable to increase greatly the sizes of power trucks, but it is not practicable to increase greatly the sizes of horse-drawn trucks, due to the limitation of the individual horse power.

Therefore, when large quantities of refuse can be collected within a short distance, large motor trucks will generally be economical, as in densely populated sections of a city. From transfer stations to final disposal points horses no longer provide the cheapest transportation.

The expense of purchasing a motor truck, and allowing for fixed charges, as well as for the additional cost of the stop-and-start service, is much greater than that of horse-drawn carts or trucks having the

same capacity. Its cost per hour, therefore, is much greater. In order to justify this excess of cost, a motor truck must be used for a correspondingly greater amount of work per hour. It does its maximum work when it is loaded full and moving. Therefore, it must get its load quickly, make short stops, and as few of them as possible.

This requirement tends to rule out motor trucks for the house collection service of garbage, where the loaded increments are small, and the stops are frequent and sometimes of long duration.

Trailers, drawn by horses, may be used for house collections, and when filled hauled to convenient points, from which a train of three or four may be taken by an auto truck to a transfer station or the place of final disposal. (See Fig. 52.)

The following information has been gained from several cities:

Boston.—The City operates two 5-ton, rear-dump, electric trucks for collecting ashes, rubbish, and street sweepings. The trucks make house-to-house collections, and deliver the material to dumps.

New Bedford.—A private collector operates one 3-ton, gasoline truck for refuse collection.

Lawrence.—A 3-ton, gasoline truck is operated by the Health Department for refuse collection.

Jersey City.—A private collector operates one 3-ton, gasoline truck for refuse collection.

Detroit.—The City operates two 3-ton, gasoline trucks for removing garbage from hotels and restaurants.

Lansing.—The City is collecting with a motor equipment consisting of one Duplex, four-wheeled truck of $3\frac{3}{4}$ tons capacity, with a trailer of the same size, requiring three men. The large truck is especially advantageous in winter, when roads are bad. There are also about half a dozen smaller trucks in use, of 1 or 2 tons capacity, each requiring two men.

Rochester.—It is reported that the economical low limit of haul for motor trucks is 2.25 miles.

Atlanta.—The Street Cleaning Department operates several gasoline trucks for collecting mixed refuse from houses and hauling it to the city incinerator. (Fig. 34.)

Joliet.—The City operates a 3.5-ton, gasoline truck equipped with an automatic, rear-dump body. It is used for house-to-house collection of garbage.

Asheville.—An electric truck is used for house-to-house collection of garbage. The body is all steel and water-tight, and has a number of hinged covers. It is dumped from the rear by a hand-hoist.

Washington.—Prior to July 1st, 1918, both the collection and disposal of the garbage were under one contract. Collections were made in horse-drawn vehicles, each carrying a metal tank body having a capacity of about $2\frac{1}{2}$ cu. yd. The filled tanks were removed from the running gear at a transfer station within the city limits and placed on rack cars for rail transportation to the disposal plant about 30 miles down the Potomac River in Virginia.

The District took over the work at that time and has continued it along the same general lines, but has used motorized equipment for making collections from hotels, restaurants, and other large garbage producing centers in the down-town districts.

MIAMI, FLA.—For the collection of garbage and rubbish, Miami has five $3\frac{1}{2}$-ton and two $2\frac{1}{2}$-ton motor trucks, and two 2-horse wagons, and, in addi-

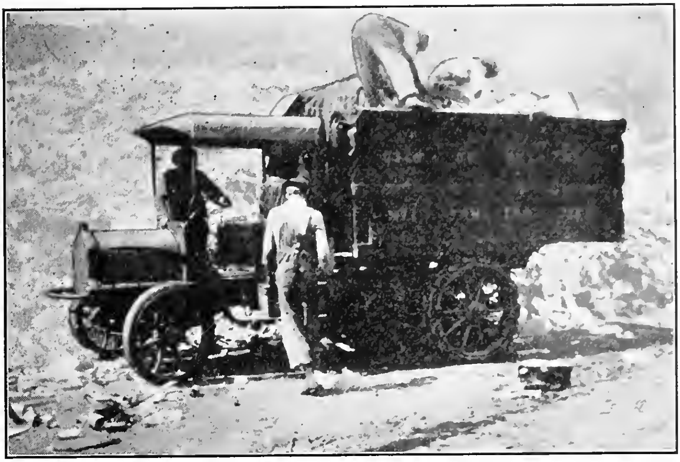


FIG. 34.—Refuse Collection Truck, Atlanta, Ga.

tion to the drivers, has 25 laborers. The daily cost of operation, including the wages of the drivers, gasoline, oil, repairs, and depreciation in 1920 was:

5 $3\frac{1}{2}$-ton trucks	at $13.00	$65.00
2 $2\frac{1}{2}$- " "	" 11.00	22.00
2 2-horse wagons	" 6.00	12.00
25 laborers	" 2.75	68.75
		$167.75

The daily collection of garbage has been 15 tons; and of rubbish, 30 tons. The average length of haul is $1\frac{1}{2}$ miles. The cost per ton for collecting garbage and rubbish is $3.73.

Miami has also operated a 2-ton electric truck for house-to-house collection of garbage. This vehicle has two flat decks, on which the cans are placed. Starting in the morning with a load of clean cans, one was left at each house from which a full can was taken. The cost of the truck was $3300, and the cost of operation, exclusive of fixed charges, amounted to about $9 per day. This included the wages of two helpers for loading the truck.

SALT LAKE CITY.—From August, 1918, until August, 1919, collections were made with two $3\frac{1}{2}$-ton trucks and one 2-ton truck, each drawing one or

two $2\frac{1}{2}$-ton trailers, all with specially built steel dumping bodies and with compartments to keep the garbage separated from other refuse, as noted from an article in *Engineering News-Record* of May 13th, 1920.

It was found that, on account of the excessive costs of upkeep of the trucks and trailers, the abuse which they received from the class of labor it was necessary to employ, and because the trucks had to be continually stopped and started when collecting from house to house, the expense was too great. Therefore, in August, 1919, their use was discontinued, with the exception of a $3\frac{1}{2}$-ton Federal truck with trailer, which is used at night. This truck and trailer, supplemented with two 2-horse outfits with specially constructed bodies on the wagons, collect at night all the refuse in the business district.

Los Angeles.—Refuse is collected from the outlying districts with motor trucks. The full load is hauled an average distance of 8 miles. Two $2\frac{1}{2}$-ton trucks collect about 300 tons of garbage per month. Garbage was formerly collected from these districts by 3-horse outfits, each making one trip a day. Teams are still used in the short-haul zones.

During the last two years, trucks have been introduced at Missoula, Butte, Dubuque, Springfield, Mass., and elsewhere. There are, therefore, many cities where motor trucks are used in the refuse collection service.

In view of the large decrease in the number of horses in the Metropolitan District of New York, it seems that the motor truck will soon replace the horse, at least, in industrial and commercial work. The delay in substituting the power trucks more rapidly is ascribed, not to the first cost as much as to the expense of upkeep of material and of apparatus which deteriorates very rapdily.

After a thorough study, the Efficiency Division of the Chicago Civil Service Commission reported, in July, 1915, that the introduction of gasoline and electric trucks in place of horse carts was not justified on account of the expense.

For a 3-ton truck or tractor the report gives as first cost $4000 for gasoline, and $5000 for electric trucks. The fixed charges per year are $1894 for gasoline and $1887 for electric trucks.

The operating expenses per mile were:

	Gasoline	Electric
Depreciation	$0.05	$ 0.03
Tires	0.06	0.06
Maintenance and repairs	0.03	0.03
Oil and grease	0.005	0.005
Energy, gasoline $13\frac{1}{2}$ cents per gallon, electricity $\frac{1}{2}$ cent per kw.-hr.	0.034	0.005
	$0.179	$0.130

The trucks are nearly all operated by gasoline. Electric trucks are most satisfactory on level roads, and can be used safely only when

electric power is readily available. As the incineration of refuse can produce steam and steam can produce electricity, it is practicable to use the latter for loading the storage batteries which can be placed on the collecting trucks. For other methods of final disposal, gasoline motors for collection purposes, even on steep grades, are more likely to be preferred, because of their easier and less delicate operation.

10. Wagon Attendants.—The number of attendants going with each collection wagon generally varies from one to three. Thus, at Milwaukee, with 1.5-cu. yd. wagons, there is one man. At Buffalo and Newark, with 4.0 to 5.0-cu. yd. wagons, there are three and sometimes four men to the wagon. In such cases one man works on each side of a street, bringing the cans to and from the curb, and the third man empties them into the wagon. This is sometimes termed the " roller " system. At Toledo, with 3-cu. yd. wagons and at Cleveland with 2.5-cu. yd. wagons, there is one attendant in some districts and two in others. In Chicago and Pittsburgh, with 4.0-cu. yd. wagons, there are two men to each wagon.

The selection depends on the location of the house can, the length of wagon haul, the time available for collection, the relative cost of teams and men, the density and character of population, and other local factors. It is found in practice under average city conditions that one man can collect from about 70 to 75 houses per hour when the cans are placed at the rear door and that from 275 to 300 houses constitutes a good day's effort. If the cans are at the curb, the number may be increased up to about 500. The following compilation is typical: Assume two hours of haul out of an eight-hour day for one load. During the six hours for collection one man would have time to collect from about 420 houses, which is too many for a single load, and is too much effort for one man. If two loads are made, leaving 4.5 hours for collection (an extra half hour is gained because one trip to and from the barn is eliminated), the wagon with two men can make collections from more than 675 houses. The greater use of the team must be balanced against the cost of the extra man.

11. Equipment in Some American Cities.—For the collection of garbage in the large cities of Ohio, a special equipment is provided. There are two general types of wagons. In Cleveland, Columbus, Cincinnati, Dayton, Steubenville, and Zanesville covered tank bodies of steel are used. In other cities of the State the wagons are built with two platforms on which the householders' cans are placed directly. The Cleveland and Columbus wagons are alike, and are designed for dumping their contents without removal of the bodies. In Cincinnati and Dayton the bodies may be removed from the running gear, transported to the point of disposal, and dumped. The platform wagons

holding the cans are somewhat less economical than the tank wagons, but are suitable for small cities where the quantities of garbage are not great.

In the smaller cities of Ohio, the collection wagons go directly to the disposal plants, but in the larger cities, where the length of haul becomes economically important, transfer stations have been established, where the garbage may be dumped into specially constructed cars, or left in the wagon bodies to be placed on flat cars and transported to the point of final disposal. The latter method is practiced in all the large cities in Ohio.

In 1910 only three Ohio cities, Cincinnati, Cleveland, and Dayton, had organized refuse collection systems for ashes and rubbish. Others depended on private scavengers. Although the separate collection of these two materials is practiced in Ohio in certain localities, they are generally collected and disposed of together.

Dayton has a modification of the slat-board type of wagon. Local conditions are met at Cincinnati by the use of a back-dump wagon manufactured by the city street-cleaning department, and at Cleveland by the use of a bottom-dump wagon of standard make. The opinion seems to prevail that, for the best economic results, where there is a combined collection of ashes and rubbish, the wagon should have a capacity of from 3 to 4 cu. yd.

In Westmount, Que., the city forces collect all refuse together in the same carts during the summer, or from April 18th to November 18th, when there are only small quantities of ashes. During the five months of winter the ashes are large in quantity and are collected separately from the garbage and rubbish. After delivery they are sifted through screens of $\frac{7}{8}$-in. mesh. The fine material is dumped or taken away free for private use; the coarse material is mixed with garbage and rubbish, and burned in the incinerator. The average number of loads collected daily varies from 6 to 8, according to the season. The average haul is about 1 mile, or from 12 to 16 miles a day for each cart. In the winter large sleighs are used for collecting. These have two compartments, one opening at the rear and the other at each side. In the summer the two-wheeled Scotch dump cart, drawn by one horse, is used. Three men attend each cart.

In Ottawa, Ont., there is no separation of refuse, ashes, or garbage all being placed in the same receptacle. The collections are made once a week, except that in summer the business section has an extra collection.

The collection wagons are larger than in many American cities, as they carry about 7 cu. yd. An arrangement of canvas and chains is placed on the bottom and up to the front of the wagon before it is

loaded; then, when the wagon arrives at the incinerator or dump, the chains are attached to a cable and the load is rolled out at the back, the tail-board having first been removed.

12. Equipment in Some European Cities.—Greater advances have been made in European than in American cities in the development of the equipment required for refuse collection. This is partly due to the greater age of European cities, and partly to the fact that in most cases foreign officials have taken up the problem in a more scientific way, and have made prior trials and tests to determine the most suitable equipment for the particular needs of the district in question.

The wagon equipments in Europe vary somewhat, but the development toward standards has gone farther than in America. Where modern wagons have been adopted, they are constructed to receive and discharge the refuse from the house cans without exposing it to the air. In nearly all cases, they are designed to be operated in conjunction with standard cans. A greater advance was possible, because the people are accustomed to comply more readily with the regulations of the municipal departments.

Fig. 35 shows a typical horse-drawn wagon for collecting combined refuse, as used in Bremen, Germany. It has lower and upper loading doors at the rear and also upper doors at the sides and toward the front. This arrangement of doors facilitates the loading by reducing the height to which the cans must be lifted before they are dumped.

Electric trucks are being used in Hamburg, Germany, for refuse collection. The body has a capacity of about 5 cu. yd., and the cost of the truck in Germany is about $4000. The total weight is about 11,000 lb. It is fitted with two electric motors, each of 4.5 h.-p. A truck can make four trips each night, covering about 35 miles in eight hours. At the end of each night's work, the batteries are replaced with others freshly charged with electricity generated at the city refuse incinerator. The cost of operation in Hamburg, reduced to cents per cubic yard per mile, is given as follows:

Tires	0.84 cent
Power	0.70 "
Miscellaneous	0.20 "
Total	1.74 cents

These are very low figures. The superintendent in Hamburg stated that the motor truck was only then cheaper than two-horse wagons of similar capacity, when operated in two shifts of eight hours per day, which distributed the fixed charges over a large tonnage of refuse. (Fig. 36.)

G.—ORGANIZATION

Efficient service in collection work depends largely on the organization and the methods of operation used in the collection. It should

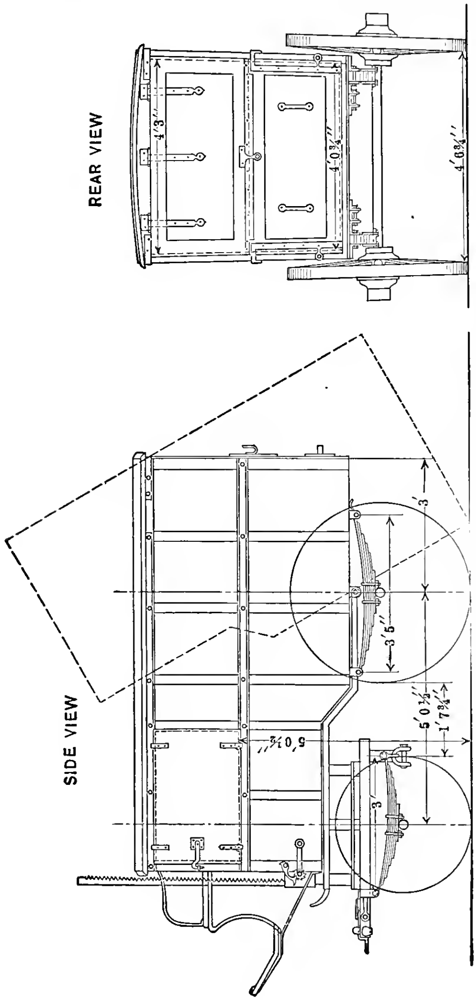


Fig. 35.—Refuse Wagon, Bremen, Germany.

be adapted both to the character of the city and to the detailed requirements of the service.

There should be a single responsible head controlling and directing the activities of a suitable number of assistants, who, in turn, should

control and direct the men in their various duties down to the last detail, so that harmonious work results with a minimum loss of efficiency and time. There should be a complete system of daily reporting, so that the character and amount of all the work done in the service is fully known, as well as the time devoted to each kind of work.

In at least the larger cities it is customary to uniform the men, which not only draws attention to their authority, but more effectively generates the consciousness of responsibility. Table 52 contains data regarding the uniforms in many cities.

Fig. 36.—Electric Truck for Refuse Collection, Hamburg, Germany.

There are three typical systems of collection operation in American cities.

1. Municipal collection, by the municipality with its own equipment and working force.

2. Contract collection, by which the city pays a private party or corporation to do the work with its own or the city's equipment. In some cities the contractor is permitted to charge the householders a fixed sum for the service.

3. Scavenger system, whereby, under license or regulation of the health department, certain individuals are permitted to collect the garbage and rubbish within defined areas of the city.

This latter system is, as a rule, impractical for large cities, because of a lack of centralized organization, but in communities of less than 25,000 population it may be satisfactory and efficient. Its success, in any case, depends on the organization and the enforcement of regu-

lations. The fewer the collectors, the more easily is their work supervised, and the dangers to public health confined and safeguarded.

For the larger cities the preference lies between contract and municipal collection.

Evidence seems to support the contention that municipal collection is more sanitary, and that contract collection is more efficient along financial lines; but the better sanitation of municipal collection is deemed worth the extra cost. The permanency of municipal collection and the value of this to public service is another strong influence which is likely to induce American communities to adopt this method.

H.—OPERATION

1. By Municipality.—In the majority of large cities throughout the United States, and in Europe almost exclusively, the collection is done by the municipality. The city controls, if it does not always own, the collection equipment; and the men employed in the work are directly responsible to their superiors, who, in turn, are responsible to the public. Some cities own the wagons and hire the drivers and horses by the day or month; in others the wagons are also hired. Municipal operation is generally found to give the greater satisfaction, for the following reasons:

1. Sanitation, not profit, is the primary consideration, and supervision is more readily effected.
2. Greater flexibility of the service is secured to meet the ever-changing conditions of season, weather, population, etc.
3. The work is directly under the control of public officials, whose chief object is to render good service to the public, at the house and on the street, at a reasonable cost; thus eliminating the not unnatural tendency among some contractors to do, within the terms of the contract, as little as practicable and with the least expenditure of money by themselves.
4. Direct responsibility to the public produces quicker results.
5. It is less expensive, generally, because the equipment investment is permanent; and no fund is necessary to meet emergencies, and no profit is included.

There are, however, certain disadvantages in some cities in operating refuse collection by the municipality, as follows:

1. Business principles are sometimes sacrificed to political machinery, when it demands unnecessary changes in appointments, methods, etc.
2. The operation of refuse collection may fall into the hands of incompetent and untrained officials.

Where the municipality owns the plant, or hires and directs the labor, municipal operation is carried out in America under the direction of either the Health Department, the Street Cleaning Department, or a special bureau of the Department of Public Works. In some instances the work is divided between the Departments of Health and Public Works. The Health Department does not generally undertake more than the garbage collection and disposal, and there is a tendency to relieve it even of some of this portion of the work. Recent reorganizations of Health Departments describe their relation to refuse disposal as largely supervisory. They should inspect the work of the refuse collection department and its results, merely as regards the suppression of odors and nuisances, to protect public health, and secure a high standard of cleanliness.

The development of refuse collection and disposal in Milwaukee during the last ten years is characteristic of the progress made in the management of such work in the Central West. Previous to 1910, the city's ashes and rubbish were collected under the Department of Public Works by a superintendent in charge, but there was no distinct bureau for this purpose. Garbage was collected by the Department of Health, under a superintendent reporting to the Commissioner of Health. In 1910, the Department of Public Works was reorganized, and a division of street cleaning created. This division handled the collection and disposal of all refuse materials, as well as cleaning the streets. The superintendent in charge of the division appointed a superintendent to handle the collection of garbage for the entire city. He also appointed ward superintendents to control the work of collecting ashes and rubbish and the cleaning of streets. These ward superintendents also supervised the maintenance of dumps. The final disposal of garbage was entrusted to a superintendent of garbage disposal.

This organization was an improvement over the earlier method of handling the work. Further betterments might result if the city were divided into about half a dozen districts, with a foreman, in charge of each one, to look after all the work in his district. The disposal works require a special foreman. This division would place the responsibility in the hands of a few men, each of whom could become thoroughly acquainted with the special requirements of his own district. In Detroit the work is thus organized, the city being divided into eight districts.

In New York City, the Superintendent of Street Cleaning has charge of a department which is separate and distinct from all others, but is limited to the Boroughs of Manhattan, Brooklyn, and The Bronx. The work is divided into various bureaus, respectively charged with

street cleaning, refuse collection, and final disposal. For large cities such an organization has many advantages. It is the common one in most European cities.

In New York, Washington, Boston, Cleveland, Detroit, Columbus, Rochester, etc., the collection equipment, including the horses and vehicles, is owned by the city.

New York officials advocate municipal operation for collection and disposal, but state that the work must be standardized, and each man's task clearly defined. Detroit officials are unanimous in the opinion that all collection should be done by city forces, but believe that the final disposal should be by contract in the case of a reduction plant, because the frequently changing personnel of city governments is not favorable to continuity of operation; and also that the person who is responsible for the operation of the plant should also be its designer. Trenton would not change to the contract method of collection because the people co-operate better with municipal collection, and are less inclined to litter the streets. St. Louis and Buffalo claim that better and cheaper work is done if the collection is by the municipality.

In Chicago, the collection and disposal of all refuse is handled by the Bureau of Streets, which is a part of the Department of Public Works. The Superintendent of this bureau is appointed by the Commissioner of Public Works, and reports to him. He has three Assistant Superintendents, each one being assigned to a different part of the work. The actual supervision of the teams and laborers falls to the various Ward Superintendents. The teams, drivers, and vehicles are hired by the day. After an investigation of the collection of refuse in Chicago, the following recommendations were made by Osborn and Fetherston:

"(1) The city should both own and operate all the equipment and works necessary for a complete system of collection, transportation, and disposal of all classes of city wastes.

"(2) That regular and systematic collection of separated classes of wastes (ashes, garbage, and rubbish) be made at daily or tri-weekly intervals, depending on the character of the districts served and the seasons of the year.

"(3) That the laws regarding the separation and handling of the different classes of wastes by the householder be given such revision as may be necessary to bring them into proper correlation with the policies as to collection and disposal recommended and to secure their effective enforcement.

"(4) That the separation of all refuse into the designated classes be made by the householders, except in the districts where the combined refuse is to be disposed of by incineration.

"(5) That a competent technical staff be employed to develop, install, and operate for at least one year the project hereinafter recommended, and to

make such further studies and tests as may be necessary to determine in detail the most suitable type of receptacles and equipment for a motor collection service."

2. By Contract.—The work of collecting refuse has been frequently let out to contractors who own the equipment, as, for instance, in Philadelphia, Buffalo, Reading, Boston, Newark, San Francisco, and other cities. Some are now contemplating a change to municipal collection. In the different cities the form of contract and the scope of the work differ. In some the work is let to a single contractor, and the term may vary from one to ten years. In others, individual collectors are licensed to do the work. Frequently, quite elaborate specifications are prepared to govern the contractor's work, and a force of inspectors is necessary, on the part of the city, to see that the contract and specifications are fulfilled.

Contracts for doing municipal work are usually limited to terms of from three to five years. For such short terms, requiring a large investment, contractors do not provide the most durable equipment or build works on a permanent basis, nor can they secure men with sufficiently long training. A ten-year term of contract would be better, although risking the vicissitudes of strikes, panic, or war. With long terms and a more permanent equipment, such as could be afforded by the larger cities, lower costs for a satisfactory service might be secured by contract.

Under the contract method, it is necessary to specify the exact character of the work to be done and also the requirements which obligate the contractor to furnish the desired service. He is required to maintain an efficient organization and sufficient equipment. Rigid inspection and control by the municipality is necessary in order to secure satisfactory work.

Therefore, broad and rigid specifications must be prepared for the guidance and control of the contractor. These should cover the following subjects, among others:

Definition of refuse,
Removal of refuse,
Refuse receptacles,
Frequency of collection,
Maps showing routes and districts,
Time for collections,
Number of collectors,
Collection wagons,
Cleaning of wagons,
Emergency wagons,
Penalty for injury to house cans or property,
Penalty for failure to collect,
Disinfectants,
Complaints,
Telephone service.

Provision must be made for a bond of sufficient size to insure full and faithful performance, a bonus for better work than specified, and a

penalty for breach of contract or for insufficient work, sufficiently large to make such action highly unprofitable. Complete and detailed regulations should be included in the contract.

Philadelphia is one of the few large cities where collection by contract is still practiced. A recent report,* however, made by city officials, concludes that the contract system is disadvantageous, and that in the future the collection should be made by municipal forces.

The advantages of the contract system are:

1. The application of business principles is more readily effected.

2. The elimination of politics from the operation removes some chances for unsatisfactory changes in the working force.

3. A simplification of the work of the municipality is advantageous, chiefly in smaller towns.

4. A definite sum of money is fixed in advance for the work.

5. Borrowing funds for constructions and purchase of supplies is obviated, as the contractor must raise the capital.

The disadvantages of the contract system are:

1. Profit, not sanitation, is the predominating influence. The contractor's criterion is the least sanitation permissible at the least cost.

2. Operation is less elastic, and contract profits may be reduced by sudden unforeseen occurrences.

3. Response to unforeseen occurrences is less rapid. Breach of contract may produce unsanitary service.

4. As usually no records of details are kept, it is difficult for the city to make estimates of cost and of efficiency of service.

5. The uncertainties in ascertaining the approximate quantities of refuse to be collected.

6. Lack of concern for public welfare invites failure to give full service.

7. Lack of direct responsibility to the public causes hindrance to expeditious action.

8. Uncertainty of contract renewal causes an excessive charge for use of equipment.

9. The apparently frequent difficulties in letting a contract for a long term, partly in view of strikes, panic, or war.

10. In view of the foregoing uncertainties, the contract system, especially for large cities, is frequently more costly.

Notwithstanding these disadvantages, the contract system has in some instances given good results.

3. Routing the Wagons.—Various methods of conducting the actual collection are found in different cities. The so-called "roller" system has been practiced in Buffalo, New York, and Springfield, Mass. Workmen go down each side of the street, about

* "Report on the Study of the Methods of Street Cleaning and Collection and Disposal of Municipal Wastes." *Journal*, Engineer's Club, Philadelphia, August, 1920, p. 326.

one hour ahead of the wagons, and roll or wheel the cans out to the curb. The men may be provided with small trucks for this purpose. Then the driver empties the cans into the wagon, and, in some cities, sprinkles them with a disinfectant. Men follow the wagons and roll the empty cans from the curb to the back yard. This method makes the best use of the time for this most expensive part of the service, and has special advantages where the house can is not easily accessible. The use of electric and other motor trucks in the collection service demands a rapid loading and a minimum time of stopping at each house. The " roller " system of collection, therefore, may prove of advantage in connection with power-driven collection wagons, as in Hamburg, Germany.

For the collection of garbage, the City of Milwaukee is divided into about 200 small districts, and these are arranged so that each one, when visited at regular intervals, yields one full load of garbage. A collector is assigned to two districts, one with a long and the other with a short haul, or he has two districts having together an average or medium-length haul. The city covers an area of about 25 square miles, and, in 1910, had a population of 385,000. Ninety-five collectors were required to serve the 200 districts. The small district system has the advantage of permitting the collector to become familiar with his district. One superintendent, with an office at the incinerator, has charge of the collection work. The weighmaster serves as his assistant. The districts have no relation to the political boundaries of wards or precincts.

Where the workmen are of sufficient intelligence to co-operate fully with the householder, this system proves quite satisfactory. In some cities the wagons carry only 1.5 cu. yd. of garbage, and the drivers furnish their own horses. Consequently, men of small means—and sometimes of small intelligence—purchase the necessary horse and vehicle in order to get a place on the city pay-roll. The work is too large to be handled effectively by one superintendent with a weighmaster as assistant, and the collectors, as a rule, do not give to the service more than the mechanical operation of their equipment.

The collection of ashes and rubbish in Milwaukee is under the direction of the Ward Superintendents, the city being divided into 35 wards, so that each Superintendent has charge of a comparatively small district. He plans the collection to suit the special requirements of his district, in accordance with his personal knowledge of the residents, the locality, and the money appropriated each year.

Recommendations which were made for the improvement of garbage collection in Milwaukee included the use of wagons having a capacity of 4 cu. yd., and the appointment of two Assistant Super-

intendents, who would endeavor to secure better co-operation between the collectors and the householders.

In Minneapolis, a city covering about 53 sq. miles, with a population of more than 300,000, the collection of all the refuse is under the Health Commissioner. The city is divided into 31 districts, which are the same for garbage, ashes, and rubbish. A city ordinance requires that all garbage shall be drained of water and wrapped in paper before it is placed in the can. (See Chapter I.) Thus, also, a lot of rubbish is collected with the garbage. For the 31 districts there are as many collectors, and each is held accountable for the removal of garbage, ashes, and certain portions of the rubbish. The collectors are paid $100 per month (1915). Their duties are to maintain a clean district—not to render service for a given number of hours per day. The minimum standard is one collection of mixed ashes and rubbish and one collection of garbage from each household per week. The good work done by the Minneapolis department is claimed to be partly due to separating the collection districts from those which are purely political.

Columbus has a refuse collection department as a part of the Board of Public Service. The principal duties of this department are the collection of garbage, rubbish, and manure. Due to the use of natural gas, only a small quantity of ashes is produced. During 1912, curb collections were made twice a week from July 1st to October 1st, and once a week at other times. Between July 1st and October 1st, 24 teams were engaged in the work, and, during the remainder of the year, 18 teams. There are 18 collection routes, each divided into two sections, one requiring a long haul to the transfer station and the other a short haul. The routes are grouped so as to give each team, as far as possible, about an equal number of miles to travel per day, the limit being an average of about 16 miles. Each team collects two loads daily. The city owns the collection equipment, including horses and vehicles, and operates stables, blacksmith shops, and a farm for raising corn.

Arranging the routes so that a wagon visits each house at approximately the same time, on fixed days of the week, offers an advantage in promoting a satisfactory household co-operation. Time schedules have been arranged in this way at Buffalo, and at Bremen, Germany. This method of routing enables a superintendent to follow the work of the collectors more carefully than otherwise. In Bremen, notice of the collectors' approach is given by the ringing of a bell. The same system is practiced in certain parts of Chicago.

4. Day or Night Collection.—The question of night as against day collection must be answered in each city by the existing special con-

ditions. There is some sentiment in America against night collection, chiefly on account of the noise, and of the cans sometimes being stolen when set out at night for the collector. In down-town districts, however, it is often difficult to make collections in the daytime because of the crowded streets.

Mr. William H. Edwards, formerly Commissioner of Street Cleaning in New York City, stated, in a paper read before the American Public Health Association in 1913, that night collection would be advantageous in New York City. He objects to the unsightliness of cans standing in front of buildings during the day, but adds that receptacles can be kept covered more easily then than during the night. The receptacles are less of an obstruction to pedestrians in the night than in the day, but, when placed within an areaway, it is sometimes difficult for the collector to find them at night. The effect of the heat of the sun radiating from pavements in summer is a further and distinct drawback in day collection, both for men and animals. The spilling of material from the wagons is still another disadvantage of the day collection. With night collection this nuisance can be obviated by the early morning cleaning of the streets. On the other hand, supervision of the work at night is more difficult than during the day, and in the dwelling-house districts, the noise of the work is a disadvantage.

In Milwaukee, during the summer of 1910, there was a public outcry against having the collection wagons on the streets during the day. The schedule was changed so that collections were made early, from 2 to 10 A.M. This worked well in summer, but during winter it was more difficult to get sufficiently rapid work, and it was necessary to change the schedule again, so that collections were made in winter from 4 A.M. until noon. This use of early morning hours in summer and winter, by combining advantages of both day and night collections, seems to have been quite satisfactory.

In European cities it is quite common to collect in the early morning. In Paris collections are made from 7 to 9 A.M. in summer and from 8 to 10 A.M. in winter.

5. Private Collection.—In some of the larger cities, where, in certain districts, the municipal collection of garbage was not satisfactory, private organizations, or improvement associations, have been formed to do this work. In 1913 it was found that in Chicago there were approximately 130 such organizations. Twelve of these reported annual expenditures totaling $139,833 in 1911, and more than $166,000 in 1912. Such organizations, when maintaining the same efficiency as city departments, cannot ordinarily do the work as economically. Private collections, however, will probably continue

to be made from hotels and restaurants, particularly in the larger cities, because of the profit realized from the sale of garbage for feeding. In Rochester, the collection contractor is not required to remove, without additional payment, garbage from groceries, canning factories, and similar establishments when in excess of 250 gal. per week for any single establishment.

I.—TECHNICAL BOARDS

In Chicago a so-called "Technical Board" was established, made up of members of the Bureau of Streets and of the Efficiency Division of the Civil Service Commission. This board had for its object the development of an efficient co-operation among the officials of the Bureau of Streets by the establishment of improved methods, the creation of an expert force to maintain the proposed measures, the training of experts for future department heads under the promotion system, and the more certain recognition by the Civil Service Commission of good or bad service in the bureau. The same object, in a modified form, is accomplished at Toronto, Ont., where a special engineer was appointed to serve with the Commissioner of Street Cleaning to develop and improve the collection service. The development of the Technical Board in Chicago and its ample financial support was recommended in a report by Osborn and Fetherston. Such boards aid in satisfying the increasing demand for better service in the cleansing departments.

J.—EUROPEAN DATA

In Europe, the collection and disposal of refuse in small cities is generally in the hands of private persons; in medium-sized cities it is under contract, and in large cities the work is done by the municipality with a permanent force of men. Some data from our private notes of trips to Europe, prior to and including 1911, are summarized briefly herewith.

The general trend of European practice is to collect all refuse together, and in one rather small house-can set out on the sidewalk; the collections are frequent, mostly daily, and the wagons are comparatively large and have fixed covers.

In England the *Proceedings* of the Association of Cleansing Superintendents contain much valuable information. In the Poplar District of London, collections are made at least twice a week from small bins placed on the sidewalks. The one-horse carts used are of wood, and are dumped by tipping over the rear axle.

In Birmingham, in August, 1919, it was the intention to establish a dual refuse system, requiring two cans at each house, one to receive only the ashes and sweepings and the other the garbage and rubbish. The collecting wagons were to be divided into two compartments for the two classes of material. The ashes and sweepings were to be screened, and the fine dust—about one-half of the total quantity—was to be delivered to farmers as a dressing for land, the rest was to be dumped on low land. The garbage and rubbish were to be emptied on a long traveling belt from which the valuable materials were to be picked out and the rest used for fuel in the plant. Tin cans were to be de-tinned. During the war, rags found a ready sale. Cotton and wool were separated, washed, dried, and sold.

In Paris, the pails are emptied into collecting wagons—usually two-wheeled—before 8 A.M. One man (*le charretier*) stands on the wagon and receives the pail, empties it, and spreads the contents. A woman (*la retrousseuse*) cleans the pail and sweeps up from the street surface any refuse that may have dropped. Two men take the pails from the house to the wagon. In 1895 about 2200 men and 560 wagons were engaged in this service. Of the wagons, 71 were drawn by three horses, 458 by two, and 31 by one horse. It has been proposed to make the collection hours from midnight to 6 A.M. The Paris wagons contain an average of 4.5 cu. m. (5.9 cu. yd.) of refuse, or 2.5 tons. In the interior of the city each filled wagon has a route of about 1.5 km. (0.9 mile) a day, and is operated about seven hours.

In Zurich, the collection work is done by the city. Collections are made twice a week. Receptacles are placed at the curb. The wagon bodies are divided into three compartments or receptacles, each separately removable. Their net capacity is 3100 lb., and there are ten men and two horses for each wagon.

In Hamburg, refuse is collected by the city from cans set out on the sidewalk. Collections are made between 11 P.M. and 9. A.M. The wagons carry 2 tons net, and are hauled by two horses. Recently, some electric trucks have been used, the power being derived from storage batteries charged at the city refuse incinerator.

In Cologne, collections are made at night (10 P.M. to 6 A.M.) and six times a week. There are 52 wagons for a population of 400,000. The cans must be of metal, and must be placed at the curb and removed before 7 A.M. Each can must have a handle and a hinged cover.

In Barmen, the city makes collections with one-horse wagons, each holding 88 cu. ft. The wagon bodies are of wood, lined with iron, and fitted with small hinged metal covers.

K.—SPECIFICATIONS

When it is found better to have the collections made by contract, and it is desired to ask for bids for the collection or disposal of garbage, ashes, rubbish, etc., it is necessary to advertise the prominent features of the proposition. If good bids are to be expected from responsible firms, sufficient time should be allowed to permit prospective contractors to study the project and become familiar with all the conditions. The notice or advertisement should be published, not only in the local newspapers, but possibly in those of large near-by cities, and also in the technical journals.

The notice should state the length of time of the contract; the available facilities which may be furnished by the city, such as the use of docks, street-railway lines, etc.; the approximate location, respectively, of transfer stations, points of delivery, dumping sites, or areas to be filled in; the hours when the collection is to be made, or the areas in which the collection is to be restricted to certain hours. Information should also be given as to payments, penalties for infraction of rules, etc.

The general instructions to bidders should contain complete information as to the preparation and submission of bids, and as to guaranties, sureties, bonds, etc.

In the specifications the principal words or terms, such as "garbage, "ashes," "rubbish," etc., should be closely defined, so that there may be no misunderstanding.

There should be a statement in full of the general work the contractor will be required to do; what plant he shall furnish, as horses, carts, drivers, tools, and implements; the limits of the territory in which the collection is to be made, its subdivision into districts, and points where loads are to be delivered; the hours within which the work is to be done, etc.

A paragraph should refer to city ordinances and State laws, and provisions for procedure, if new ordinances or laws should have the effect of increasing or decreasing the cost of the work.

The method of inspecting the contractor's plant and his method of collection, should be specified, and also the officers of the city who are to be satisfied with its efficiency.

There must be a clause in reference to receptacles for garbage, ashes, etc., for instance, that, if required, separate receptacles for these materials will be provided by householders; that other refuse will be secured in packages; that garbage cans will be water-tight, have close-fitting covers, and be of such a size as to be easily handled

by one man; that receptacles will be placed where easily found, as at the curb line, etc.

As disputes may arise regarding the place where a receptacle is to be left for collection, the specifications should make the method of deciding them clear.

Streets or parts of streets are sometimes closed temporarily, by the construction of sewerage or other works, and the specifications should state that the contractor's men are to carry the garbage, ashes, etc., to the collection wagons.

It may be necessary to provide that on certain streets the collection of garbage, ashes, etc., shall be made before 9 A.M., also, that special collections shall be made in certain congested districts without extra compensation, and that the contractor be allowed to readjust his routes to accommodate such special collections.

It is desirable to specify that the contractor shall visit or pass through, with a sufficient number of carts or wagons, all present and future streets, and cart away all ashes and non-combustible refuse at least once or twice a week, and on such days as may be prescribed by the proper officer. It may also be well to specify a separate collection of garbage, from May 1st to October 1st every day (Sundays excepted), and from October 1st to May 1st at least three times a week, on alternate days, as fixed by the proper officer. It may also be advisable to indicate certain districts in which the collection of garbage, ashes, etc., shall be made more frequently than in others.

It should be specified that the contractor shall issue to each household a card, in accordance with city regulations, stating the days (and approximately the hours) when the collection of garbage, ashes, etc., will be made, and that he should give due notice when changes in the time are made necessary.

In reference to carts, wagons, etc., it is advisable to specify in the contract that they shall be uniform in construction, and so that each may be loaded, carry its load, and be unloaded without giving offense to the public. Such vehicles should be strong, numbered, and marked to indicate the nature of the material carried, kept in repair, well painted, thoroughly cleaned, and, after each delivery, disinfected with disinfectants furnished by the contractor, so that it will be free from odor at all times.

It should also be specified that all animals used in hauling carts or wagons shall be strong and serviceable horses or mules. If gasoline or electric trucks are to be used, certain information should be given as to their capacity, tires, wheel base, construction, etc.

The inspection of all animals, vehicles, and plant of every description furnished by the contractor must be provided for.

It should be specified that vehicles, when in motion, shall be kept tightly closed, and, while being filled, shall be opened as little as possible. A penalty may be imposed for the infraction of rules.

It may be possible to make arrangements with the street railway service for the transportation of garbage, ashes, and rubbish between certain points and within certain specified hours, and, if this can be done, the specifications should contain the necessary provisions regarding payments, etc.

The contractor should make a weekly or monthly report of collection work done, quantity removed, in cubic yards, and the approximate tonnage of loads in vehicles of different sizes. Separate returns should be made of garbage, ashes, non-combustible refuse, and of mixed refuse or whatever may be collected.

It should be specified that the contractor shall (or shall not) be the owner of all or of certain parts of the material collected.

The contractor should be required to maintain an office, with telephone connection, within the city, and be in communication with the proper city officers at all times, in order to receive and transmit orders, etc.

The city may designate the places where ashes and non-combustible or other clean material shall be dumped for the purpose of grading streets, etc., and provision should be made for payment for any increase in the average haul in such cases. Provision should be made as to arbitration in any case of dispute relative to compensation for increase of haul.

Among the general provisions it should be specified that the contractor shall do his work in such a way as to create no nuisance; that all material of any kind spilled or scattered on sidewalks, gutters, or roadways shall be swept up by him; that all receptacles or vessels for garbage, ashes, or other refuse, after being emptied, shall be returned, without injury, to the places from which they were removed.

The penalties to be paid by the contractor for infraction of the terms of the contract and specifications should be stated in detail, and also the method of making payments to him.

It should be specified that the contractor will not be permitted to sublet the whole or any part of the work, or make any assignment of the contract or any interest therein, or of the moneys to be paid thereon, without written permission from the city authorities.

L.—SUMMARY AND CONCLUSIONS

The foregoing statements show the great need for efficiency and economy in the collection of refuse materials, because it is frequently

the most important and costly single element of the entire refuse problem, and one where improvements, chiefly in equipment, can most readily be made. The collection requires well-organized and effective co-operation between the householder and collector, and a cleansing department which operates along thoroughly business-like lines.

The equipment should be carefully adjusted to the specific needs of the locality, and standardized as much as practicable.

The collections should be regular. They should be along well-planned routes, studied carefully to get the largest loads in the shortest time along the easiest roads. The frequency of collection should depend on the method of final disposal, on the season of the year, and on the geographical location of the town. The time of collection should be selected so as to give the least inconvenience to people and traffic moving on the streets. The manner of collection should be such as to remove the refuse from house to wagon in the least objectionable way. The loading should be done so that it will produce the least possible dust and noise, and the wagons should be kept covered for as much of the time as practicable. The data herein recorded furnish many experiences and suggestions in these directions.

Depending on the size of a city and the efficiency of its government, the collection should be made either by permanent municipal forces, or by contract under carefully prepared and detailed specifications, and operated under an efficient and experienced supervision. Private collection from hotels and restaurants, and in small towns under equally good supervision, may be found advantageous occasionally.

In order to increase the efficiency and the economy of the collection, it would be well to establish more records for comparison on the man-hour and ton-mile basis. The labor employed should be competent, intelligent, and faithful. Short, daily reports should be made in a simple but fairly complete manner, giving route, number of houses visited, and kind of refuse collected. All complaints should be followed up, checked, reasons ascertained, and causes of trouble remedied. All practicable incentives should be given for effective work. A card should be kept at the office for each house, and collections, troubles, payments, etc., recorded thereon.

CHAPTER IV

SUPPLEMENTAL TRANSPORTATION

A.—PURPOSE

In large cities the refuse removal from the houses does not always end with the collection service. When the length of haul for delivery is excessive, supplemental methods of transportation become more economical. As cities grow, and congested districts spread out over larger areas, the available sites for disposal works are found only at greater and greater distances from the center of production, and the greater becomes the need for a secondary method of transportation. The new problem which then arises is the transportation of the refuse from the economical limits of collection haul to the points of final disposal.

In New York City there was for many years no nearer suitable location for a garbage reduction plant than Barren Island, about 20 miles from Manhattan by water; and transportation to the island by boat was necessary. At Cleveland, a transfer station could be established about $\frac{3}{4}$ mile from the City Hall, and the favorable location for a garbage reduction plant was found to be at Willow, about $9\frac{3}{4}$ miles from the center of the city, and, therefore, transportation by rail was required. Chicago, covering a greater area than any other city, also required secondary means of transportation. A part of its garbage is taken by barge through the Chicago River to a reduction plant in the Stockyards. Parts of the ashes, rubbish, and street cleanings are taken, either by trolley car or by freight car, from transfer stations in the city to dumps on the outskirts; and manure is taken on freight cars to farming districts, some distance from the city.

The terms "Relay Station," "Transfer Station," or "Loading Station" generally refer to a station where refuse is transferred from the collection vehicle to another vehicle which is to transport it to the point of disposal.

The term "Loading Station" means specifically a station on a railroad, or on a water front, where railroad cars, or scows, may be loaded from the relay vehicles or from the original collection vehicles.

The transfer or relay of a load may be made either by dumping from the collection vehicle into a skip or other transfer arrangement from which the refuse is in turn dumped into a semi-trailer and truck, or a truck and four-wheeled trailer by which the refuse is transported to the loading station or the point of disposal. This arrangement is followed in Brooklyn.

A second method is by transferring to another vehicle the body of the vehicle in which the refuse is collected, as in Detroit, Cincinnati, and several other cities.

A third method is by collecting in a horse-drawn vehicle which can be used as a trailer behind a tractor. Such a vehicle is usually a four-wheeled trailer and is hauled to the disposal point, or the loading station, in trains of several vehicles. Such an arrangement is used in Utica, Buffalo, Bridgeport, Memphis, and numerous other cities.

These supplemental methods for transporting refuse to greater distances are required chiefly for economical rather than sanitary reasons; yet there are also sanitary demands. These arise at the stations where the refuse is transferred from the collection wagons to cars or boats. Several examples of reloading or transfer stations, inappropriately designed and operated, could be cited where, through improper design or carelessness, a nuisance has been created. Such stations must always be built with special reference to preventing dust from blowing away during dumping, offensive odors from polluting the air, and the spilling of refuse between the wagons and the cars. There should be ample provision for cleaning every part of the station, and particularly the dumping platforms and tracks.

Refuse collection service, as already described, includes two parts: the house-to-house collection, and the transportation of the material from the point of first delivery to the place of final disposal. The first part constitutes a so-called start-and-stop service. The second is a straight run. The first corresponds somewhat to ice-delivery service or package-delivery from a department store; the second corresponds to coal-delivery.

The economy of supplemental transportation of refuse requires the consideration of:

1. The cost of collection or team haul,
2. The cost of transportation by supplemental methods,
3. The available locations for transfer stations,
4. The available locations for final disposal.

A careful consideration of the conditions in each city may require still other determinations.

A proper analysis of all the information will determine very closely

the best relation between the lengths of collection haul and supplemental haul. Such an analysis was made for Chicago by Messrs. Jacobs and Cenfield, engineers in the Efficiency Division of the Civil Service Commission. They determined the following basic unit costs for Chicago:

Average cost of team haul per load-mile, one way	\$0.50
Average cost of dumping one collection wagon, including overhead charges	0.35

Handling the refuse materials on trolley cars required the following costs per wagon load:

Time of team at transfer station	\$0.10
Operation of transfer station	0.38
Transportation by trolley car	0.77
Handling at dump	0.08
Average cost of handling, per wagon load	\$1.33

The cost of transportation by trolley car includes the service of a motor car at \$25 per day and of two trailers, each at \$6 per day. The trains are assumed to make one trip in 2.7 hours.

Using these estimated unit costs, the relation between the haul by trolley cars and the team haul can be determined from the following equation, the results being given in cents:

$$50x + 133 = 50y + 35,$$

in which x is the length, in miles, of the team haul from the point of collection to the loading station, and y is the length, in miles, of team haul from the point of collection to the point of final disposal. With these assumptions, it is found that for any given value of y, as, for instance, 3 miles, the corresponding value of x will be 1.96 miles less, or, in this instance, 1.04 miles. It would be more economical, therefore, to haul refuse directly to the place of final disposal if the difference between the length of haul to such place of final disposal and to the loading station should be less than 1.96 miles.

The same analysis may be made in order to determine approximately the most economical locations for transfer stations in various parts of a city, which information may be used as a guide for the final selection and purchase of property. In Chicago, such an investigation resulted in the selection of several transfer stations. The Civil Service Commission estimated that an annual saving of about \$50,000 would result from this supplemental transportation, by avoiding the unusually long team hauls.

B.—AVAILABLE MEANS AND METHODS

The four principal means for a supplemental transportation of refuse materials are: boat, steam railroad, trolley car, and motor truck.

1. Boats and Deck-scows.—The use of boats or barges is now confined exclusively to a disposal at sea or on the Great Lakes, where the garbage is dumped from 10 to 15 miles from shore. At New Orleans, for some years, garbage was boated a short distance down the Mississippi River for dumping. Deck-scows were used in Boston and New York many years ago; the scows were taken to sea and the refuse was thrown overboard by laborers using pitch-forks. In New York such rather costly method was followed by the use of the Barney self-dumping scow. This vessel was built with a hinge extending horizontally along the center line of the boat at the deck level. The two halves of the barge opened at the bottom, allowing the refuse stored in the hold to drop into the sea.

A further development was the Delahanty self-propelling, automatic dumping boat. This boat is a catamaran having pockets between its two hulls. The pockets hang on hinges, and are opened and closed by the same power as that used to discharge the refuse. In this boat the New York refuse was carried to sea and discharged. The cost for transportation and delivery in 1905 was about 19 cents per cubic yard. The disposal of refuse materials by dumping at sea or in the Great Lakes, however, is being gradually discontinued, because some of the refuse eventually drifts ashore.

A shallow, hollow, or hopper barge is now used in New York for transporting garbage from the water-front transfer stations to the reduction plant or to dump at sea. The collection carts dump into the barge over a tipping board along the edge of the wharf, or the truck bodies are emptied into the scow by a derrick. The barges are then towed by a tug. Similar barges are used in Boston.

In Chicago, deck-scows are used for the transportation of garbage from the river-front transfer stations to the reduction plant. As the garbage wagons are fitted with removable steel bodies, and as derricks are available at the transfer stations, the wagon bodies can be lifted from the running gear and placed on the deck of the scow. The scows are of two types: self-propelling, and arranged for towing. At the reduction plant the boxes are unloaded by derricks.

A small, non-propelling, deck-scow for river service normally costs from \$6000 to \$10,000. A tug to haul the scow costs about \$35,000. The garbage boxes can be piled on the scows to form two or three layers. The cost of transporting garbage by this method in Chicago

during 1912 was about 75 cents per ton. The work was done under contract by a lighterage company, and the cost was thought to be high.

In Milwaukee, Wis., wagon bodies have been transported on deck-scows across the Milwaukee River to the garbage incinerator. In Frankfort, Germany, the full wagon bodies, specially designed for quick discharge of mixed refuse into the incinerator, are taken to the disposal plant down the river on deck-scows.

2. Steam Railroad Cars.—Steam railroad transportation is used more frequently now than any other method. Three types of cars are used. Garbage is dumped into so-called metal "tank" cars, or the entire wagon bodies are taken to the disposal works on flat cars. Mixed refuse in bulk is transported in standard freight cars of the "gondola" type, the sides of which are arranged to open for unloading.

Tank cars of special construction are used in Cleveland and Columbus for the transportation of garbage. These cars have now been in service for more than ten years, and satisfactory standards have been developed. Figs. 37 and 38 show the most recent design for cars of this type. They have been placed on the market by the Koppel Industrial Car and Equipment Company, and may be described as follows:

The cars are of steel, and, in every respect, are built to conform to standard M. C. B. requirements for transit on their own wheels by any railroad, and are equipped with Westinghouse air brakes. The tank carried on the car has a semicircular bottom, and rests on rockers at the ends and on rollers at intermediate points, so that it can be dumped and righted very easily by two men. The tanks are made with three and four water-tight compartments, each of which has two lids or covers hinged at the center. The capacity of the tanks is from 12,000 to 18,000 cu. ft. Five or more strong chains on each side of the car keep the tank in position during transportation.

These cars, though intended for garbage, could also be used for ashes or street sweepings. They are being used in St. Louis, San Antonio, and other cities.

The cost of these cars at Cleveland and Columbus in 1914 ranged from \$1800 to \$2500 each. The cost of transportation varies with the distance and the local switching charges. In Cleveland, the freight cost averaged approximately 20 cents per ton. In Columbus, the cost per ton has exceeded 30 cents, although in 1911 it was only 23 cents.

Part of the garbage of Cleveland was formerly taken from the loading station to the reduction plant in wagon bodies on flat cars. The bodies were lifted from the wagon to the car by a traveling crane.

Tank Car for Supplemental Transportation of Refuse.

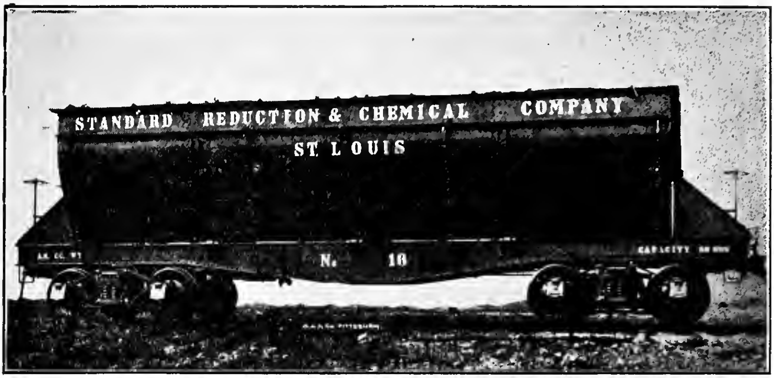


Fig. 37.—Side View.

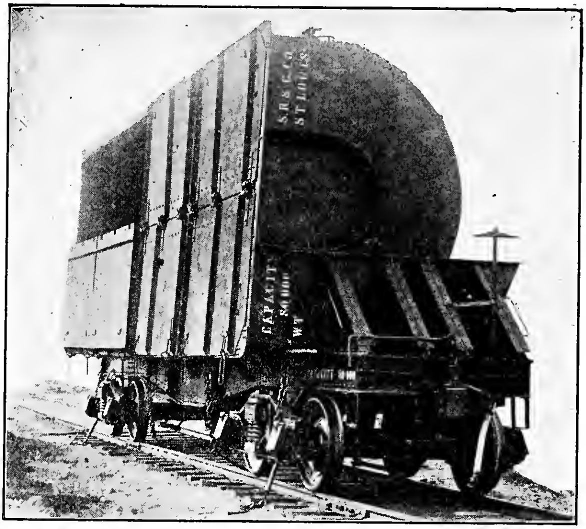


Fig. 38.—End View of Tank Car in Dumping Position.

The crane traveled on a runway which extended over the road and over the siding on which the flat cars stood. The same method of transportation is used also in Minneapolis, where the cost has averaged 24 cents per ton of garbage, including the operation and maintenance of the transfer station. It is also used in Detroit, the transfer station having a crane traveling on a runway, as at Cleveland. The wagon bodies, however, are emptied into " gondola " cars, which are taken to the works of the Detroit Reduction Company, about 20 miles distant, the city paying a part of the freight.

Ashes, rubbish, and street sweepings have been moved in Chicago on gondola-type cars. The collection wagons dump directly into the cars, and these are taken away at night, in a train of four or five, to the dumps at the city limits. The refuse materials are discharged through the sides of the cars, and are spread over the dump by hand.

Minneapolis has flat cars on which the wagon bodies are stacked. Pittsburgh has cars with high sides. In New Orleans, the garbage is taken in steel railroad cars from the transfer stations to a large dump outside the city. The collection wagons deliver it to five such stations along the belt railroad. The garbage, when dumped into the cars, is treated with a disinfectant, and a tarpaulin cover is tightly drawn over each car. At the terminus the refuse is dumped into smaller cars, operated on portable tracks, and hauled to the dump by gasoline engines.

3. Trolley Cars.—Three types of trolley cars have been used successfully in America for the transportation of different refuse materials.

First, in Brooklyn flat cars take ashes and rubbish to the dump. The collection wagons dump into large steel bins set below the dumping floor. When full the bins are lifted by a traveling crane and placed on the cars, each being large enough to hold four of the bins. (Fig. 39.) Similar flat trolley cars were used in Chicago during the winter of 1914 for transporting garbage-wagon boxes to an emergency disposal plant. In both cases the cars were fitted with motors.

Secondly, gondola-type, side-dumping cars, for trailer service over street railways, were used in Chicago for the transportation of ashes and rubbish to the dumps. These cars have ridged bottoms in order to facilitate dumping. The sides are arranged with hinges at the top, so that they swing clear at the bottom. The unloading at the dump requires from thirty to sixty minutes.

Thirdly, an improvement has been made in street railway self-dumping cars in Chicago, following the experience with the gondola type. The new type developed is called " the triple-body steel dump car, rocker type." The car consists of three bodies of equal size, arranged to dump on either side, and so that each can be dumped

independently of the others. It is used as a trailer. The three bodies, together having a capacity of 25 cu. yd. filled to a level, can carry 30 cu. yd. of refuse. The over-all length of the car is 40 ft. 6 in., and the maximum over-all width is 8 ft. 9 in. The height from the rail to the top of the bodies is 8 ft. 10 in.

The cars are carried on standard trucks, suitable for street railway service. They can be emptied in a few minutes over the side of a high dump, and so that the track can be easily maintained along the edge. In practice, there has not been much difficulty in dumping the

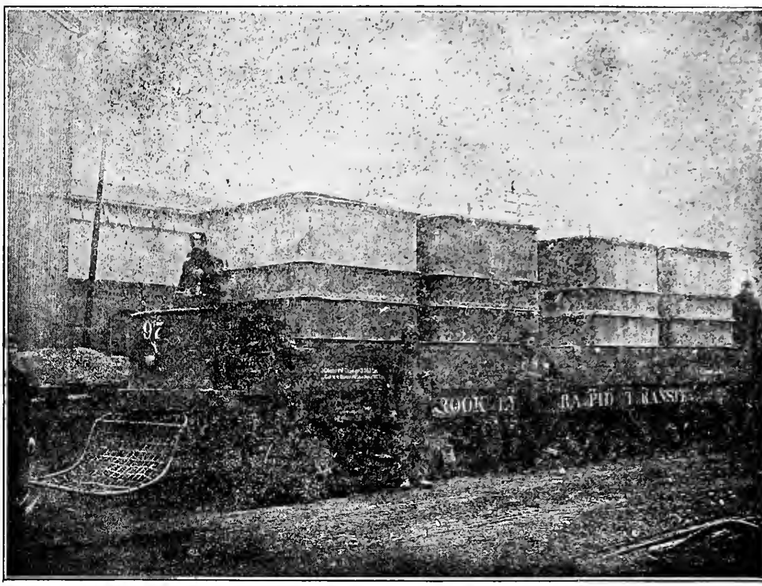


Fig. 39.—Bins Loaded on a Trolley Car, Brooklyn.
(From "The Disposal of Municipal Refuse," by H. de B. Parsons)

car bodies, and they have given good service. The first of these cars bought by Chicago cost $1600 each.

Trolley cars have been used in Philadelphia for moving street sweepings to the dumps outside the city. They were of special design, rectangular in cross-section, the sides extending about 7 ft. above the floor, giving the car an unusually large capacity. It was found that the depth of the material made it difficult to hold wet sweepings without leakage. On this account they were not as satisfactory as the steel dump cars. It is generally necessary to raise the collection wagons at the transfer station to a high dumping platform. In

Philadelphia this was done with a hoisting engine which pulled both the horses and wagons up an incline to the platform.

In Salt Lake City the garbage is transferred at a special station, within the city limits, to specially constructed railway cars and transported over the lines of the Bamberger Electric Railroad Company to the hog-feeding farm of the contractors, 7 miles north of the city, where a switch runs directly into the main building. All other waste matter is delivered at a dumping ground within 3 miles of the business district.

4. Motor Trucks.—With recent advances in the construction of motor-driven vehicles, the transportation of refuse materials by this method has increased. The principal types are the motor-driven running gear, with the refuse-containing body attached, and the tractor type, where the body is carried on a separate running gear drawn by the motor. A flat body for carrying garbage boxes or house cans is also used. Motor trucks in refuse disposal service were first used in America in Seattle, and later in Atlanta, and their use is extending.

Many makes, types, and sizes of trucks are in use, with either gasoline or electric motive power. The bodies are built to unload by dumping at the rear, or by using a rope network, as at Calgary. With a tractor, the trailers can be built for bottom- or side-dumping.

The use of motor trucks for transporting refuse from a transfer station to a point of disposal was recommended in Chicago, and the cost of operation was estimated at 20 cents per ton-mile. For garbage transportation, a motor truck was considered with a flat top on which collection wagon bodies were placed by a derrick. It was estimated that motor trucks on this service could be relied on to make 40 miles per day. Similar service by motor truck was considered for Boston by Mr. John Primrose, Engineer of the Power Specialty Company.

In selecting the size, it should be remembered that a 6-ton vehicle costs no more, in labor to run it, than one of 4 tons capacity, and less time per ton is used at each end of the journey, in getting into position, and also in loading and unloading.

Tractors have not as yet been used much for refuse transportation, though they have shown lower costs than motor trucks for a similar service of hauling stone, sand, and gravel.

Mr. Walter M. Curtis, Manager of the Engineering Department of the New England Audit Company, in 1913, made a careful analysis of the cost of haul for various motive powers. The results of his investigation are shown in Figs. 40 and 41. The costs are based on 300 working days per year, with the reservation that, where work is unsteady, and there is much idle time, the cost per ton-mile will be

increased very materially. In the case of long hauls, where the distance is too great for horses to make a daily trip, motor transportation has many advantages, and will probably increase.

A careful analysis of the use of motor trucks and tractors for hauling refuse and street-repair materials was made in 1913 by Jacobs

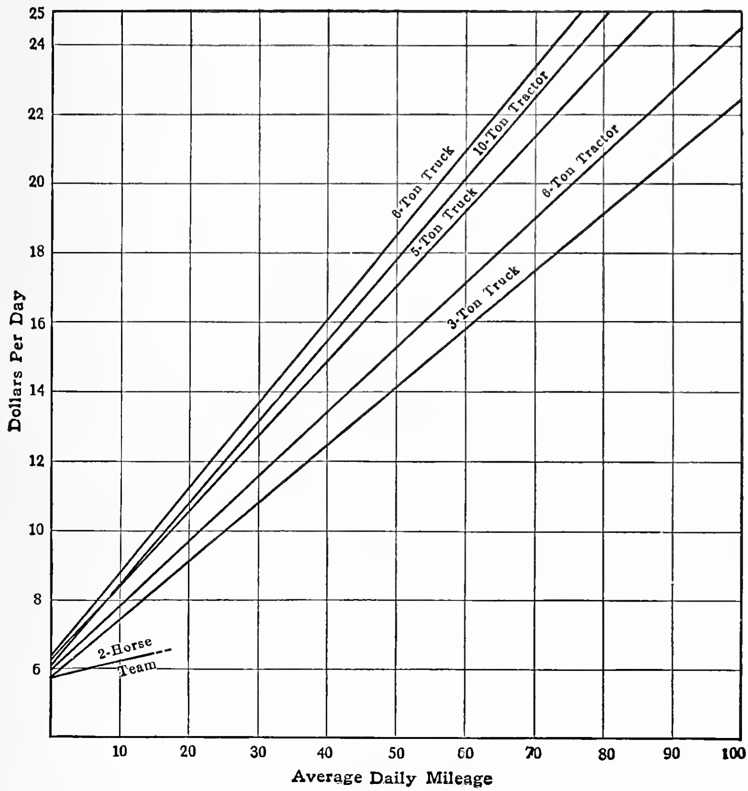


FIG. 40.—Comparison of Total Haulage Costs for Trucks, Tractors, etc.

and Cenfield for the Chicago Civil Service Commission. They reviewed the available data at some length, and compiled the charts shown here as Figs. 42 and 43. The results are quoted as follows:

"Inquiries have been made as to the adaptability and economy of motor trucks in connection with the hauling of city refuse and crushed stone and other material for the repair of streets and alleys. Tests have been made on various kinds of motor trucks in different cities of the country with varying results,

and inquiries have been directed to different municipalities and motor truck companies and several tests made in this city to determine the following:

"1. The relative economy of hauling refuse and street repair materials by motor trucks and by teams.

"2. The kind of motor truck best adapted for this purpose.

"3. The practicability and economy of discarding present equipment and the purchase of motor trucks.

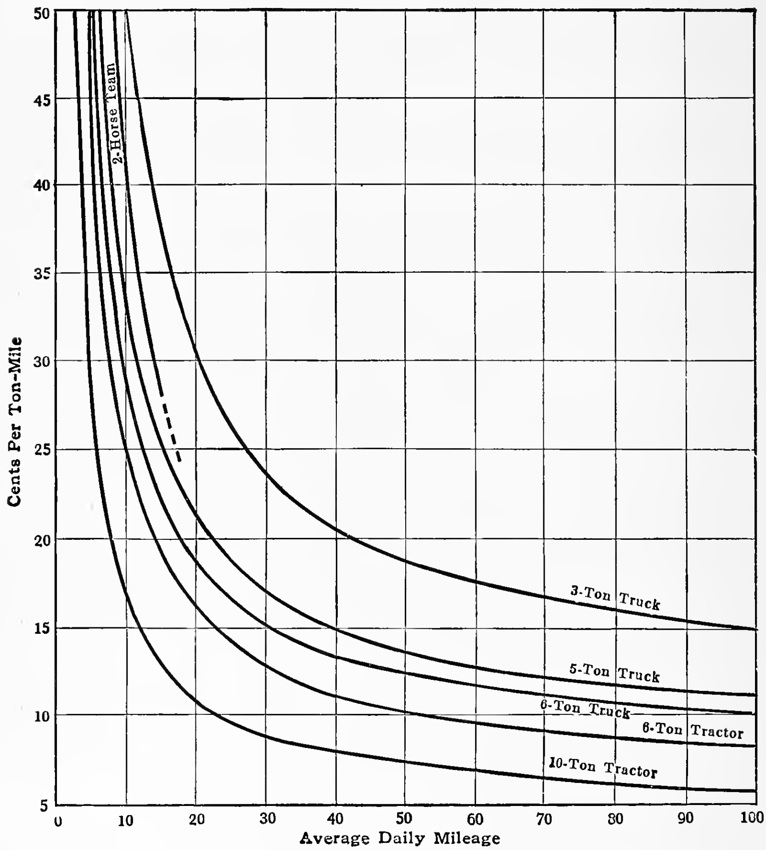


FIG. 41.—Comparison of Haulage Costs of Trucks, Tractors, etc.

"The matter of the relative economy in the use of motor-driven and horse-drawn vehicles for different lengths of haul has been treated by Mr. R. T. Dana, Member, American Society of Civil Engineers, who shows the variation in cost per ton for different lengths of haul from one-quarter mile to ten miles and the savings that would result in the use of motor-drawn vehicles. Following are his summary figures:

Length of haul, in miles	Cost per Ton		Cost per Ton-mile		Percentage of saving by using motor-drawn vehicle
	Horse-drawn vehicle	Motor-drawn vehicle	Horse-drawn vehicle	Motor-drawn vehicle	
$\frac{1}{4}$..........	$0.15	$0.19	$0.640	$0.760	−18.8
$\frac{1}{2}$..........	0.22	0.24	0.440	0.480	− 9.1
1..........	0.32	0.32	0.320	0.320	+ 0.0
2..........	0.50	0.48	0.250	0.240	+ 4.0
3..........	0.70	0.62	0.233	0.207	+11.2
4..........	0.90	0.79	0.225	0.198	+12.0
5..........	1.09	0.96	0.219	0.192	+12.3
6..........	1.29	1.12	0.215	0.187	+13.0
7..........	1.48	1.28	0.211	0.183	+13.2
8..........	1.68	1.44	0.210	0.180	+14.3
9..........	1.88	1.60	0.209	0.178	+14.7
10..........	2.07	1.77	0.207	0.177	+14.7

"Similar investigations have been made at the Massachusetts Institute of Technology, and the following summary shows the relative cost of operating the horse-drawn, gasoline, and electric commercial vehicles, based upon the different sizes of vehicles:

Size of vehicle, in tons	Number of Miles Traveled for Expenditure of $1.00		
	Horse-drawn	Gasoline-driven	Electric-driven
$\frac{1}{2}$..............	3.9	3.6	4.3
2..............	2.9	2.6	3.1
$3\frac{1}{2}$..............	2.2	2.3	2.7
5..............	1.7	1.9	2.2

"In estimating the probable economy of the transportation of pavement material by the use of motor trucks, the following assumptions have been made, based upon the experiences and requirements in this city.

"1. That five-ton trucks will be used.
"2. That these trucks be equipped with dump bodies.
"3. That the time required for loading and unloading will be five minutes.
"4. That each truck will be in actual use seven hours per day, this being liberal for necessary delays in traveling, loading, etc.
"5. That an average speed of seven miles per hour can be maintained by electric motors; eight and a half miles by gasoline trucks.
"6. That the other charges entering into the cost of operation are the same as the assumptions for three-ton trucks estimated for garbage service.

"The following assumptions were considered in estimating the economy of the use of horse-drawn vehicles for hauling the same materials:

"1. Capacity of stone wagon .... 7,500 lb.
    Capacity of asphalt wagon .... 8,900 "
"2. Time required for loading or unloading .... 5 min.
"3. Average speed of wagon .... 2.7 miles per hour.
"4. Cost per day (wagon, team, and driver) $6.00

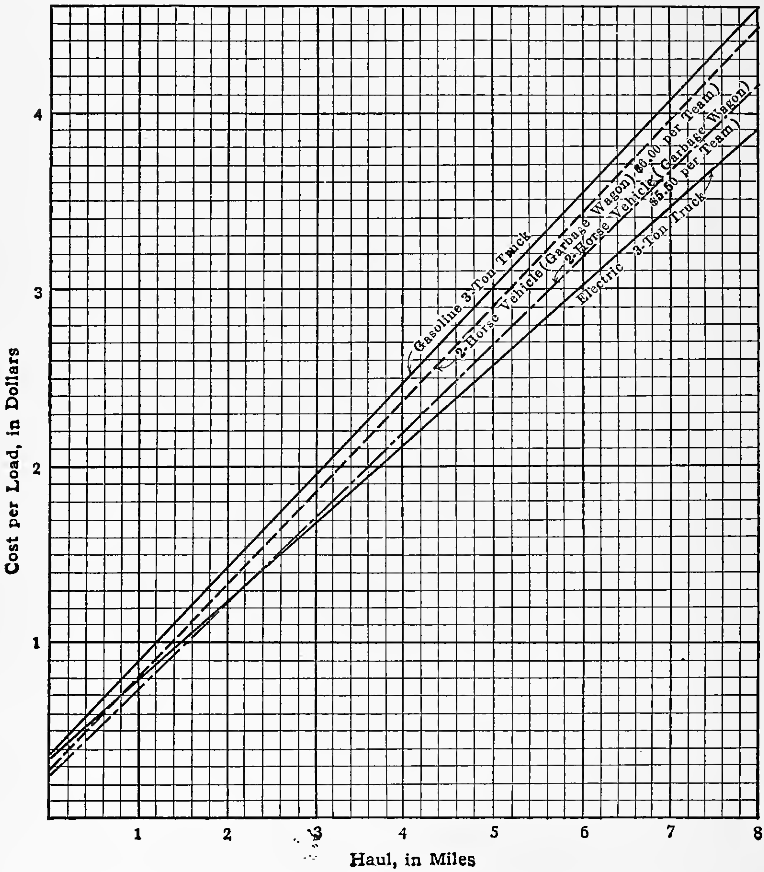


FIG. 42.—Haulage Costs for Horse-drawn, Gasoline, and Electric Vehicles of Three Tons Capacity, for Hauling Garbage.
(Chicago Civil Service Commission).

"Analyses of the estimates have been made, and curves, showing miles per day, cost per ton, and cost per ton delivered in street work, based on the

above assumptions, show that the use of motor trucks is more economical than horse-drawn vehicles when the same are used for a period of at least 300 days per year in the transportation of crushed stone, asphalt, and other street repair materials. If the period in which the transportation equipment is used is less than 180 days each year, which is the minimum period in which street repair work will be made during any year, the use of horse-drawn asphalt wagons is more economical, and the use of horse-drawn wagons for hauling crushed stone is less economical than any type of motor truck. The curves

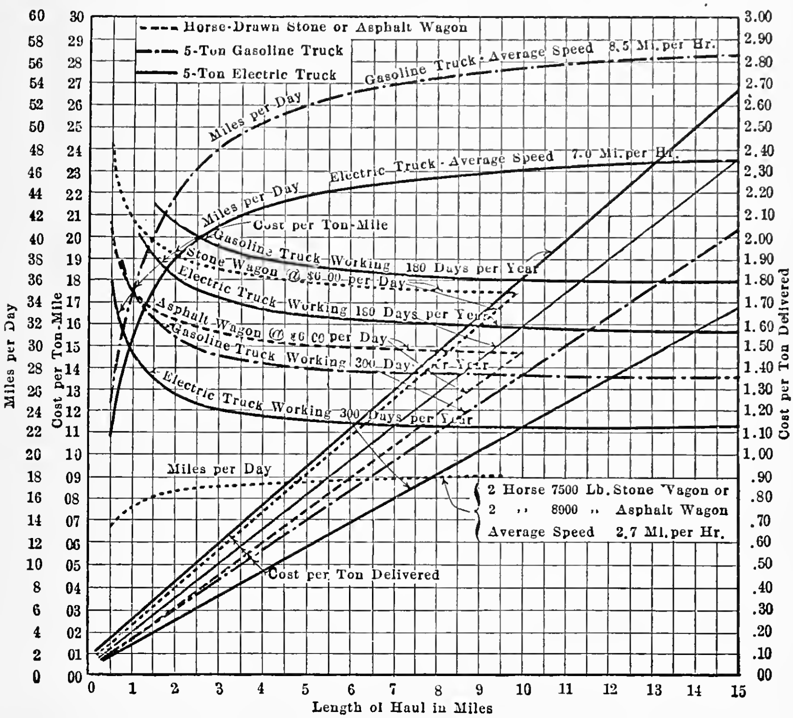


FIG. 43.—Comparison of Miles per Day, Cost per Ton-mile, and Cost per Ton Delivered, for Hauls of Different Lengths, for Street Repair Work. (Chicago Civil Service Commission.)

further show that, in order that the cost in using electric trucks instead of asphalt wagons be equalized, the electric truck must operate at least 230 days each year, and the gasoline truck must operate at least 260 days each year. Under favorable conditions, the motor trucks would be more economical than horse-drawn vehicles for the transportation of crushed stone and asphalt, and the use of electric trucks will probably show a saving of approximately 25%.

"The study of the economy and adaptability of the use of motor trucks for

hauling garbage and other city refuse, as shown above and in the curves (Figs. 42 and 43), has led to the following conclusions:

"1. That at the present prevailing cost of team hire, the saving in the use of electric motor trucks for hauling garbage, in such wards as have a considerable haul, would amount to 5.1% of the total cost of removing such garbage by teams.

"2. That, if the cost of teams were increased to $6.00 per day, the total estimated saving by using motor trucks for hauling would be about $15,775 per year, or 12.3% of the total estimated cost of teams at $6.00 per day.

"3. That, inasmuch as these estimates are computed on the eight-hour day basis, and that the present working period of garbage teams rarely amounts to eight hours per day, and often the working period is as low as six hours, that the saving which could be expected would exceed the percentage given.

"4. That either the gasoline or electric power truck can handle the hauling of garbage with comparative ease and with approximately equal satisfaction.

"5. That the more economical power truck has been found to be electric. This is governed in a measure by the low rate of cost of electrical energy from the Sanitary District to the city for night power, and the fact that the collected data on the electric truck have shown lower per cent rates for depreciation, maintenance, repair, and insurance than for the gasoline truck."

Table 60 gives some costs of transporting garbage by various agencies and in different cities during the period from 1917 to 1920.

TABLE 60.—COSTS OF TRANSPORTING GARBAGE

(From Report by S. A. Greeley on Garbage Collection and Disposal for Toledo, Ohio)

City	Year	Method	Tons of garbage	Cost of transportation per ton
Chicago, Ill.	1919	Barge	786	$0.962
Baltimore, Md.	1920	Barge	......	0.30
Detroit, Mich.	1920	Railroad	......	0.75
Washington, D. C.	1919	Railroad	53,258	0.68
Pittsburgh, Pa.	1920	Railroad	60,000	0.60
Indianapolis, Ind.	1919	Railroad	16,587	0.26
Dayton, Ohio	1919	Railroad	11,360	0.55
Grand Rapids, Mich.	1917	Railroad	10,500	0.45
Utica, N. Y.	1919	Tractor trucks	8,400	1.43
Wilkes-Barre, Pa.	1918	Truck	7,500	1.60

A brief summary of the use made of motor trucks for supplemental transportation in a few other cities follows:

New York, N. Y.—The Department of Street Cleaning operates a number of 5-ton, rear-dump, gasoline trucks. The tractor-trailer

system is used, and its equipment includes 7-ton garbage wagons having a low loading height, and 8-ton and 15-ton ash and rubbish wagons. The 15-ton wagon is built for a speed of 8 miles an hour. It is fitted with steel tires for summer use, and in winter rubber tires are put on the front wheels. The bulk of the load, however, is carried on the steel tires (Figs. 44 and 45).

Figs. 46 and 47 illustrate the demountable equipment used in New York, whereby an expensive piece of machinery—the truck—is kept at work all the year round, instead of lying idle. In winter it is used in

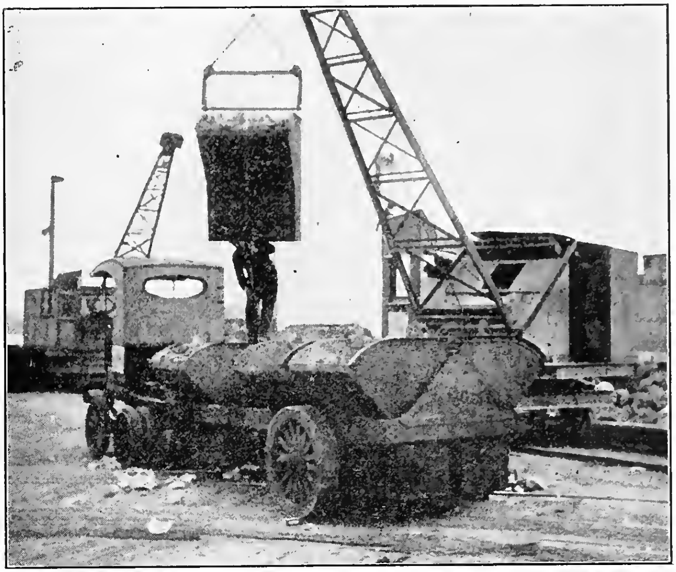


FIG. 44.—Eight-compartment Garbage Truck, New York City.

the collection of refuse and in summer for sprinkling or flushing streets. The receptacles for refuse are removed from the chassis, and the water tank, with the necessary piping, is substituted.

Figs. 48 and 49 illustrate the Read winter dump body mounted on a $7\frac{1}{2}$-ton Mack truck. It is fitted with metallic covers, and has a special automatic tail gate which is thrown up over the body and out of the way when dumping. As an indication of the principle that as much work as possible should be obtained from such expensive machinery, it may be stated that twelve of these units have been in continuous service for sixteen hours, or more, a day, for more than three years.

Fig. 50 shows an 8-cu. yd. refuse collection body on a 6½-ton Mack truck, as used by the New York Department of Street Cleaning. This body is mounted on a chassis which is designed for use with a demountable flushing equipment.

Detroit, Mich.—In the collection of garbage in Detroit, an inexpensive, one-horse, four-wheeled, running gear was used (Fig. 51). The body is a rectangular steel box, holding 60 cu. ft., and having a canvas cover. One man, one horse, and one wagon, with the box body, comprises one unit. When the box is filled it is driven to the

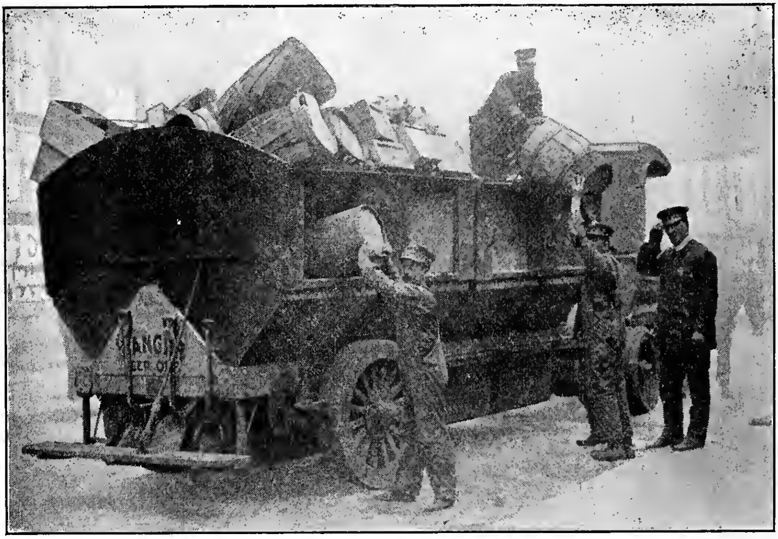


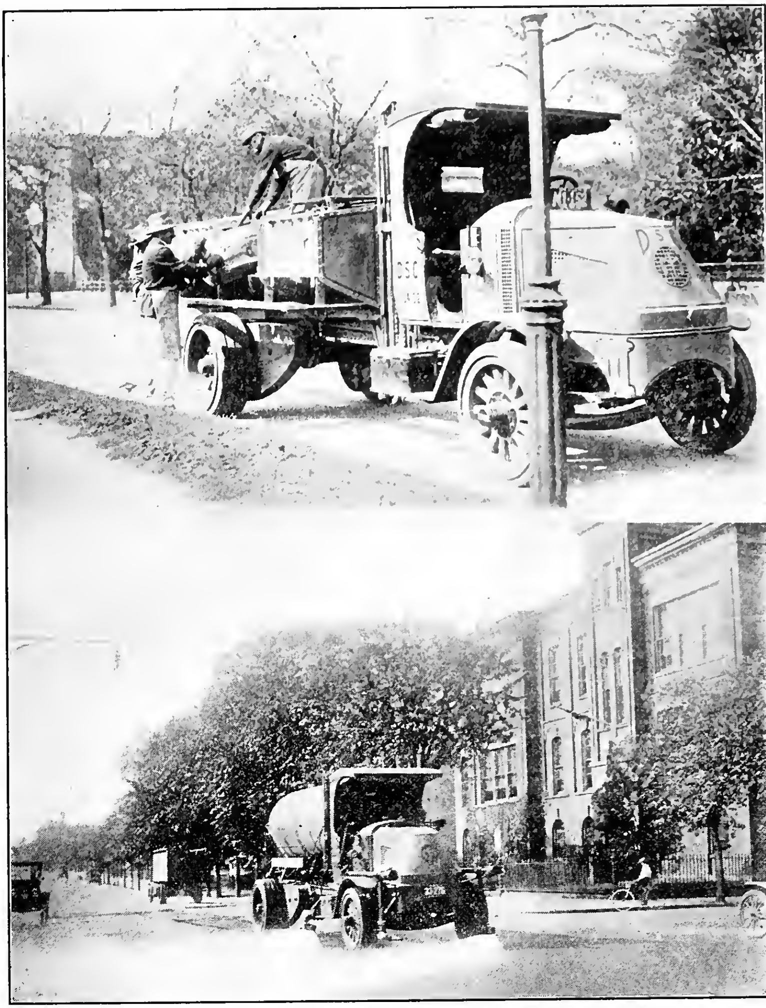
Fig. 45.—Twenty-five Yard Motor Trailer, New York City.

transfer station, where the body is lifted from the wagon by a special rig and deposited in a pile of such bodies to await the arrival of the relay vehicle. An empty body is then placed on the collection running gear to go back for another load.

Seattle, Wash.—The Department of Health has operated one 5-ton, gasoline truck for carrying garbage from a transfer station to the place of final disposal. The truck carries a 7-cu. yd., rear-dump body.

Calgary, Alta.—This city operates a number of electric trucks, covering a variety of services. The Sanitary Department has a 5-ton truck with an extra battery at the rear. This truck is used with three trailers, each having a capacity of about 16 cu. yd. The garbage is

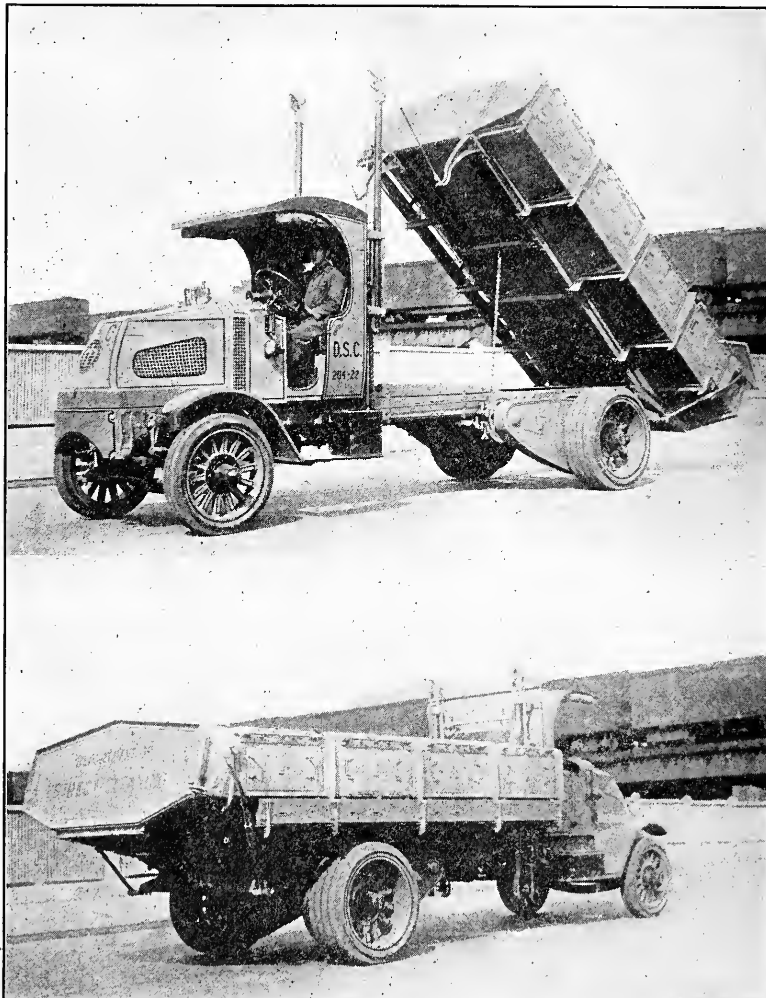
drawn by one-horse carts to transfer stations and there discharged into the trailers. A rope network is attached to cover the inside of



Figs. 46 and 47.—Demountable Equipment of Motor Truck, New York City.

the trailer body. The trailers are picked up by the truck at certain times each day and hauled to the incinerator. At the incinerator, a traveling crane picks up the rope network holding the garbage, and

dumps it into a storage pit. The 5-ton truck is said to have replaced six teams. Its cost was \$5050 (f.o.b. Calgary) complete with battery.



FIGS. 48 and 49.—Read Winter Dump Body on 7½-ton Mack Truck, New York City.

In Brooklyn, Bridgeport, Calgary, and other cities, trains of trailers are used in supplemental transportation. Fig. 52 shows a train of

three Lee trailers which are being hauled around a curve and entering a narrow alley, thus demonstrating their perfect tracking and steer-

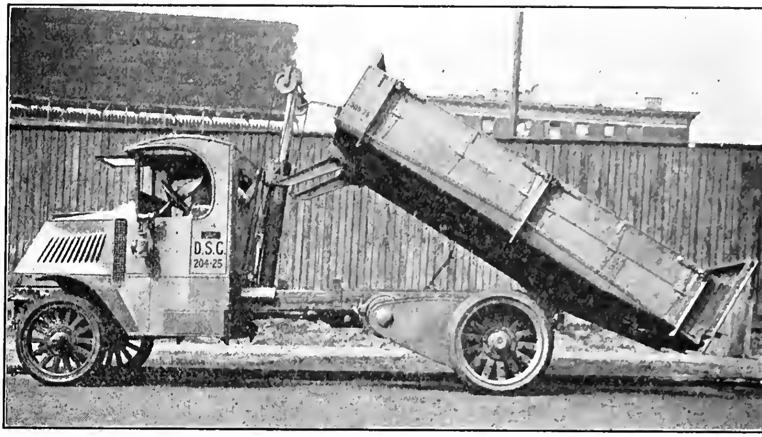


Fig. 50.—Eight-yard Refuse Collection Body on 6½-ton Mack Truck, New York City.

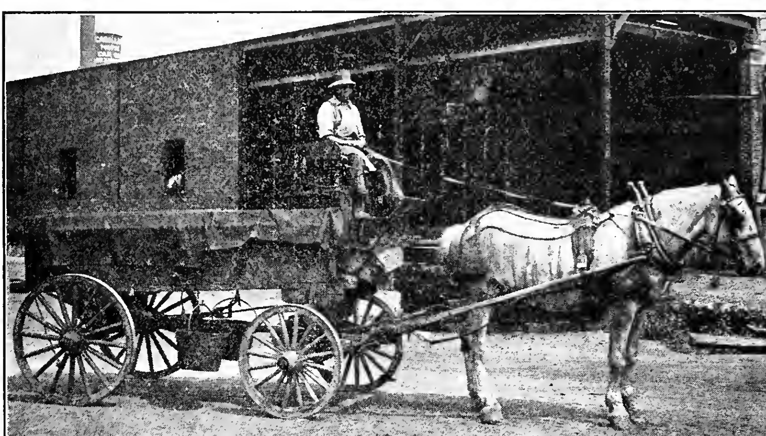


Fig. 51.—One-horse Wagon, with Removable Box Body, Detroit, Mich.

ing. These trailers are of the drop-frame, reversible type, and are dumped at either side. Each trailer is drawn by horses and used for house-to-house collection. At certain times and places three or four

of these trailers are picked up by a motor-truck and hauled to the point of final disposal.

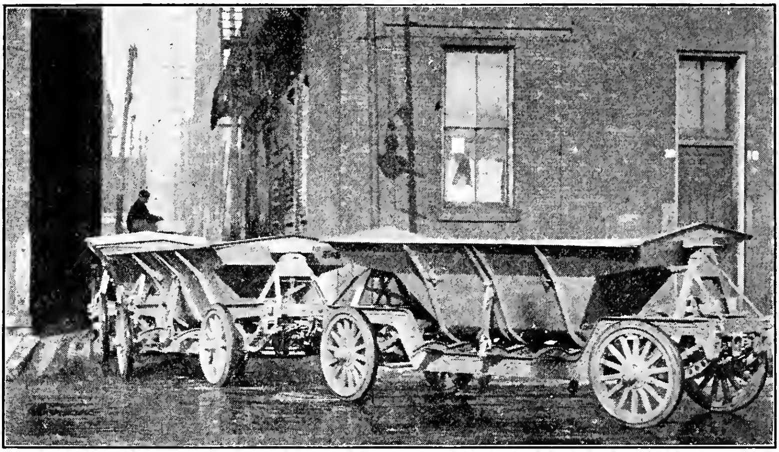


FIG. 52.—Lee Trailers, Pulled by Tractor, Entering Narrow Alley.

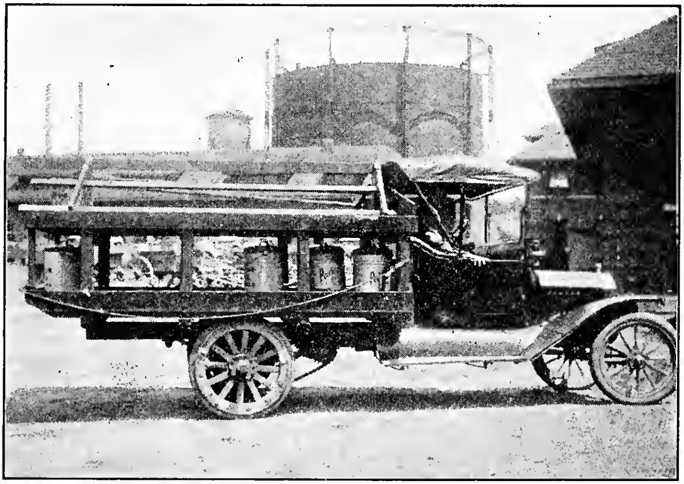


FIG. 53.—Light Motor Truck for Refuse Collection, Evanston, Ill.

Some trucks have also been used for transporting garbage to hog farms at the National Army Camps. A number are used for emergency collection service, as at Evanston, Ill. (Fig. 53).

A study of about 60 typical motor routes by the Department of Agriculture in 1918 indicated that 1 gal. of gasoline would be sufficient to enable a 2-ton truck to travel from 5 to 7 miles, a 3-ton truck from 4 to 6 miles, and a 5-ton truck from 3 to 5 miles. The depreciation might be estimated roughly at from 15 to 25%, being obviously greatest for the greatest annual mileage. It varies also with different makes, being correspondingly less with the better vehicles.

The Bureau of Markets shows a range of from 1 to 4 cents per mile for the cost of solid tires, for different loads. Pneumatic tires were found to cost more, but the annual depreciation and repairs were usually less.

To estimate the total cost there should be added garage rent, taxes, insurance, license, and office overhead expenses.

C.—TRANSFER AND LOADING STATIONS

The structures for transfer and loading stations are of several types. Some have an elevated platform with inclined approaches, the wagons being dumped from the platforms into freight cars, boats, etc. The platform should be attractively housed and have concrete floors. There should be an ample supply of water for washing, and good drainage. Usually, these conditions have not received sufficient attention. Some stations have a crane for picking up loaded wagon bodies and either emptying them into or placing them on another vehicle for further transportation.

Such stations sometimes have critical locations and require special provisions and care. In New York, Chicago, Baltimore, and Boston, there are water-front locations for boat or barge transportation. Some cities have railroad transportation. Some stations are housed; in others the platforms are not covered.

In Detroit the transfer station, Fig. 54, is a building partly walled in with brick, and having a galvanized-iron roof. It contains an electric hoist running on overhead I-beams. Periodically, according to a regular schedule, a 6-ton Mack truck and four-wheeled trailer, Fig. 55, go from the transfer station, where the full wagon bodies have been received, to a loading station at the railroad, where they are emptied into railroad cars for transportation to the disposal works. The empty wagon bodies are then taken back to the transfer station and exchanged for another load.

The loading station at Detroit is a galvanized-iron shed, built over the railroad tracks, and has several electric cranes operated on overhead I-beams. These cranes lift the wagon bodies from the truck and trailer, using a rig similar to that at the transfer station, and

convey them to a pile or directly to the cars, into which, by a simple overturning, they are emptied.

In Columbus there is a transfer station (Fig. 56) of a good type for handling garbage. It was designed and built by Osborn, and is in a central location, near the city stables. Its cost was about $15,000. The collection wagons drive up an incline with a 6% grade, then back up against a bumper board, and dump over an apron into steel tank cars below. The width of the platform within the

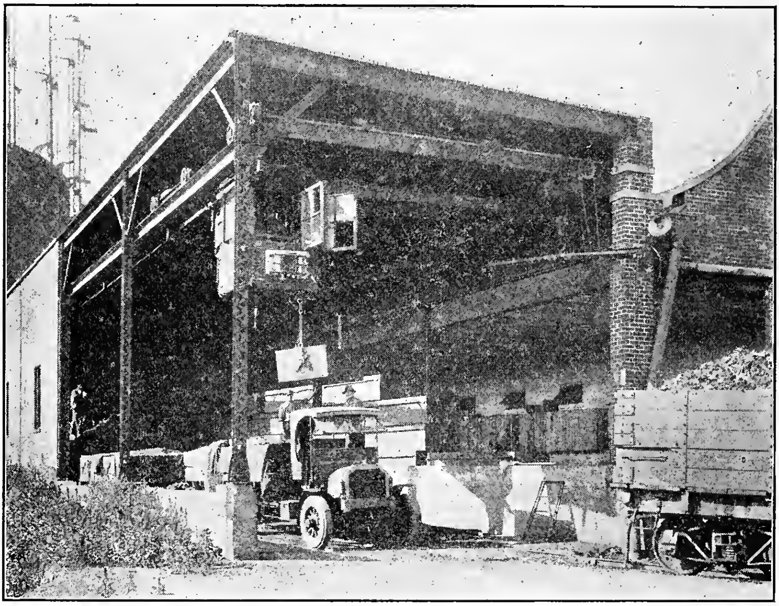


Fig. 54.—Transfer or Relay Station, Detroit, Mich.

building is 24 ft., which gives room for a two-horse team to turn and dump. The wagons are hinged about the rear axle, and are dumped by using a pulley traveling on I-beams over the bumper board. As the dumping causes some spilling of garbage about the trucks, it has been necessary to pave the space around and between the tracks, in order that it may be cleaned easily. Below the dumping platform there is a blacksmith shop and a storage room for tools. The building is of brick and reinforced concrete.

The water-front transfer stations in New York (Fig. 57) consist of wide open wharves, fitted with bumper boards at each side. The scows are moored alongside the wharf, several feet below the level of

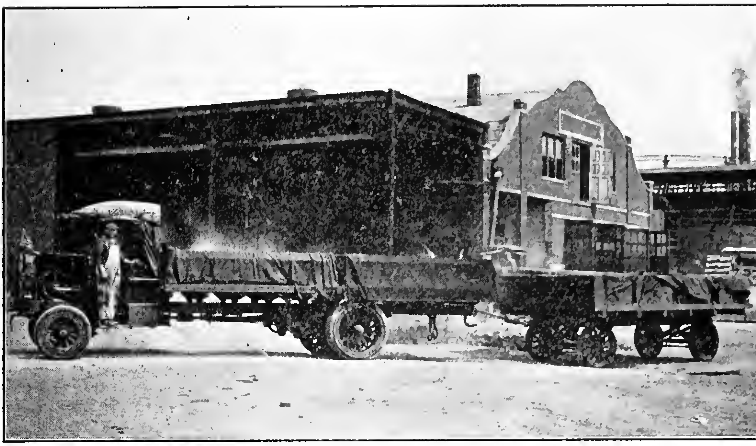


Fig. 55.—Six-ton Truck and Five-ton Trailer, Detroit, Mich.

Fig. 56.—Garbage Loading Station, Showing Inclined Driveway, Columbus, Ohio.

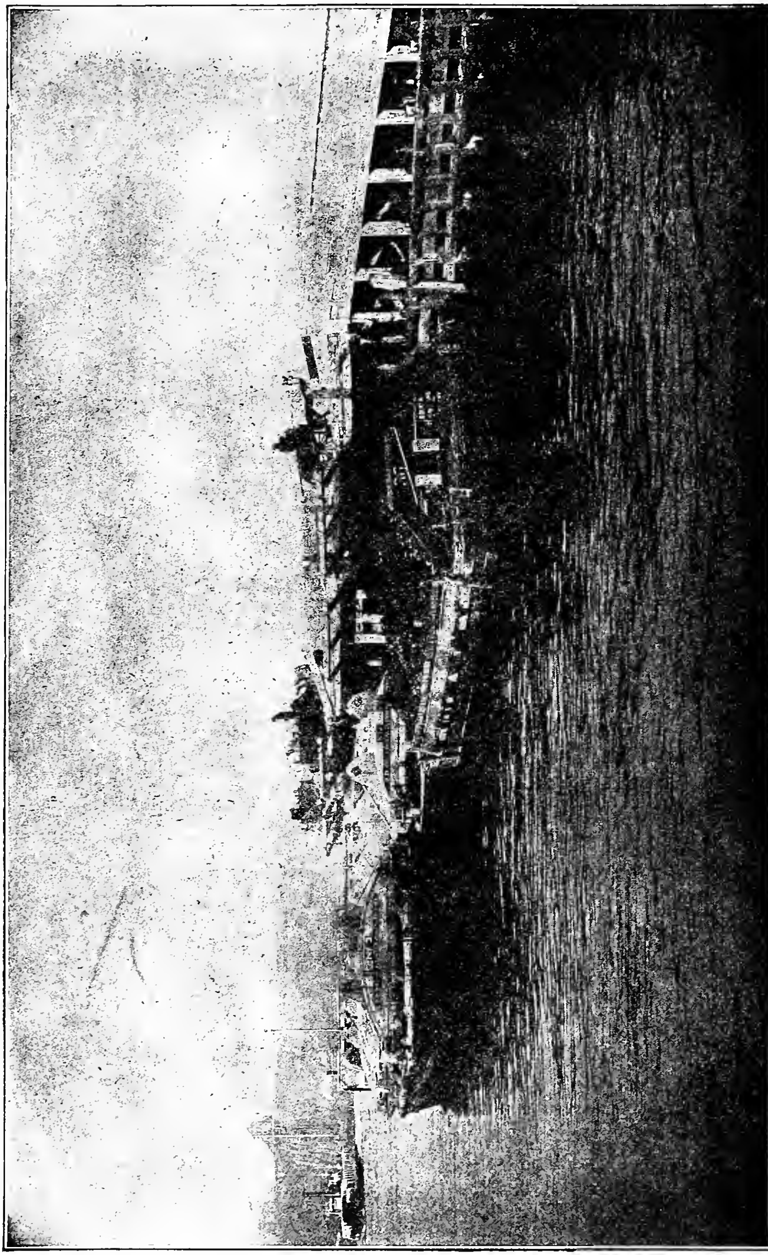


FIG. 57.—Dumping Refuse into Scows, New York.
(From "The Disposal of Municipal Refuse," by H. de B. Parsons).

the dumping floor. The collection carts back up against the bumper and dump over the edge into the scows. No protection is provided against the escape of dust and odors.

In Chicago and Milwaukee the transfer stations along the river, for transferring garbage boxes from the wagons to the scows, consist of open platforms on which there are derricks. The hoisting engines operating the derricks are housed, but otherwise no protection is provided. In Chicago, a transfer station for ashes and rubbish, built at 15th and Loomis Streets, consisted of a long platform, 60 ft. wide, accessible from both ends by easy inclines. Switch tracks from the trolley lines were built on both sides, and the wagons were dumped into cars from both sides of the platform. The latter was not enclosed, and no provision was made to prevent the escape of dust and odors.

The experience gained with this transfer station led the engineers of the Chicago Civil Service Commission to recommend one of a new type. (Fig. 58.) This new station is reached by an incline with a 5% grade, and is left by an incline with an 8% grade. The switch tracks are carried through the building under the dumping floor. Trap-doors are provided in this floor so that bottom-dumping wagons can drop their loads directly into the cars below. Rear-dump wagons can also deliver refuse through these trap-doors. The dumping floor is enclosed in a house fitted with large steel dust curtains at the runway entrance and exit. It is estimated that such a transfer station, with a capacity of 35 wagons per hour, could be built for $12,000 (1913). This price is for a structure which is not very substantial or attractive.

A transfer station of brick and reinforced concrete, two stories high and 46 by 146 ft. in plan, was built in Regina, Assin., at a cost of $16,000. A siding of the municipal street railway runs through the building at the ground level, and on this are run 5-cu. yd. steel dump-cars especially designed for transporting refuse. The loaded collection wagons reach the second floor by an approach or ramp, and dump directly into the cars.

The following requirements are found in the contract and specifications of the City of Boston for the transportation of refuse from inland and water-front stations:

From Inland Stations.—Refuse is to be transported in metal receptacles, hauled by horses or motors, or by steam railroads or street railways. Garbage must be carried in steel receptacles or tanks, and each must have an air-tight cover to be fastened down with swing bolts as soon as the receptacle is filled. The garbage is to be discharged through an opening in the receptacle similarly fastened and sealed. Receptacles for transporting other refuse are to be modified

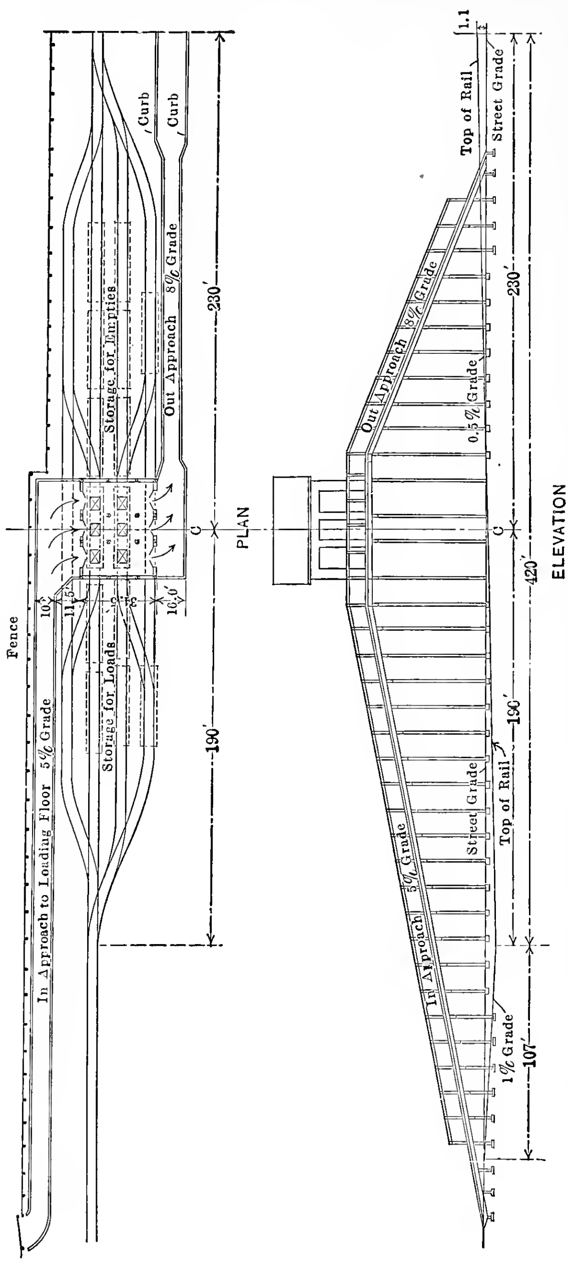


FIG. 58.—Proposed General Layout of Station for Loading Refuse on Railway Cars, Chicago, Ill.

in design so that they may be loaded and discharged rapidly. They are to be covered and secured so as to prevent the escape of flying material or disagreeable odors.

From Water-front Stations.—Refuse is to be transported in scows divided into water-tight and air-tight compartments so as to carry as much of the refuse as possible below the water line, and thus lessen the danger of overturning or spilling the refuse. The scows are to have heavy coamings, around the outside of the hold space, high enough to prevent any material from spilling overboard. The usual pumps, capstans, winches, and all modern appliances are to be provided.

When in summer the garbage has become several days old, when at the station, and foul odors and fly breeding are to be prevented, then, if the garbage is not to be fed, it is advisable to use a disinfectant, such as a cresol solution, kerosene oil, or a solution of gas-house waste.

D.—EUROPEAN DATA

The use of supplemental methods for transportation and transfer stations have not been found as necessary in Europe as in America. The reason is that in most European cities the refuse is mixed, and is disposed of by incineration. As incinerators can be built within the cities, the length of haul is short, thus obviating the necessity for supplemental transportation. Within the London Metropolis, for instance, there are fourteen local incinerators.

In England, petrol was used extensively for supplemental transportation during the war and since. The steam wagon seems to be going out of use. The electric wagon has come to the fore during the past few years. It does its best work on level roads and when not working above its capacity. It is found to be economical in operation if of a sufficiently powerful type. It is used for refuse removal in Southport and Blackpool.

In Paris there are five local incinerators. Some of the refuse is loaded on scows at the shores of the Seine and some is removed on street or steam railroads. The freight charges average 0.05 franc per ton hauled 1 km. Motor trucks have been used in Paris, Hamburg, and in other places. Barge transportation on the river Main has been used for the Frankfort mixed refuse.

E.—SUMMARY AND CONCLUSIONS

The chief factor in deciding on the adoption of supplemental transportation, provided the sanitary requirements are properly met, is the

cost. The cost per ton-mile for moving refuse materials by supplemental methods of transportation for long distances is less than by team haul. Therefore, they are often used. The larger the volume of refuse to be moved, the more economical will this method become, and its use will increase as the design of motor trucks improves.

Such transportation is secured by trolley cars, barges, steam railroads, and motor trucks with or without trailers. The local conditions and the cost should decide the best means to be adopted.

An important part of the scheme is the transfer station at which the collected refuse is delivered and transferred to the means by which it is to be transported to the place of final disposal. Such stations must be properly located at suitable places and designed so that they may be readily kept clean and be economical in operation.

CHAPTER V

ESTIMATING THE COST OF COLLECTION AND TRANSPORTATION

In the previous chapters a few cost data are given in connection with descriptions of structures and operations. In the present chapter the subject of cost estimation as a whole will be considered. The unprecedented effect of the late war on the prices of materials and on labor makes the determination of costs at present generally extremely difficult. Careful analyses, and adjustments to present conditions, are therefore especially necessary.

The abnormal conditions increasing the cost at present are: Labor shortage, decrease in the efficiency of men, higher wages, and shorter work days.

So many local factors enter into the cost of collection, haul transfer, and transportation of refuse materials, that, unless these are considered and understood, the cost data are often misleading. Standard forms for recording the cost data of refuse collection are not used extensively, so that, as the available information is not in uniform shape, it should be judged with caution, and used with qualification. In all cases, reference should be made, where possible, to the original source of information. The cost data in the following pages are classified according to the suggestions made in Chapters III and IV. Methods of analyzing the cost of various parts of the service are given first, and are followed by the actual data. Some of the data have been taken from the work of Jacobs and Cenfield. Chapter XII contains some information on the cost of collection in Chicago.

A.—ELEMENTS

The elements governing the loading, hauling, transfer, and transportation of refuse materials have been mentioned in Chapters III and IV. Those pertaining to the cost of each part of the collection service can be segregated from what has already been given, and studied advantageously by the methods mentioned in what follows. The

unit quantities used in the computations for any proposed work, must, of course, be determined for each locality and specific local condition, as the assumptions made in the following calculations are solely for the purpose of illustrating the method.

B.—LOADING

The cost of loading will vary with the character of the material, the district served, the season of the year, the unit cost for labor in each locality, and with still other local conditions.

We may analyze the cost of loading one wagon with garbage or other material, as follows:

Let n = number of persons per house or per collection;
m = number of minutes required to make one collection, or to give service to one house;
d = interval, in days, between collections;
c = capacity of wagon, in tons;
q = quantity of garbage or other material produced by 1000 persons, in tons per day;
and N = number of hours required to load one wagon.

Then,
$$N = \frac{c \times \frac{1000}{n} \times m}{d \times q \times 60}.$$

Let a = cost of team, wagon, and collector per hour;
and b = cost of loading one wagon.

Then, the cost of loading one wagon $= Na$.

Example: Assuming that

$$n = 10,\ m = 1,\ d = 2,\ c = 2,\ q = 0.273, \text{ and } a = \$0.75.$$

Then,
$$N = \frac{2 \times \frac{1000}{10} \times 1}{2 \times 0.273 \times 60} = 6.1 \text{ hours to load the wagon;}$$

and the cost to load one wagon

$$b = 6.1 \times 0.75 = \$4.57.$$

As $c = 2$, the cost of loading per ton is $\frac{4.57}{2} = \$2.28.$

The same analysis can be applied, also, to the loading of ashes, rubbish, mixed refuse, or any material, if the proper unit quantities and basic data are first determined. The cost per ton for loading other refuse materials in Chicago in 1914, in accordance with properly assumed data, were found to be as follows:

Materials	Cost of Loading per Ton
Ashes	$0.415
Rubbish	2.62
Mixed refuse	0.56

C.—HAULING

The refuse material when loaded into the collection wagon must be hauled to the transfer station or to the place of final disposal. This is done by horse-drawn vehicle or by motor. The length of haul will be from the point of last collection to the place of final delivery, and this distance must be covered twice for each separate load.

The cost will depend on the rate of travel, the weight of the load, and the cost of the team and driver, or motor and mechanic. The cost of team haul may be estimated as follows:

Rate of travel	3.0 miles per hour
Cost of outfit	$0.75 per hour
Cost per mile traveled	0.25
Cost per mile hauled	0.50
Cost per ton-mile with a 2-ton load	0.25

The cost by gasoline or electric truck may be estimated as follows:

Rate of travel	6.0 miles per hour
Cost of outfit	$2.40 per hour
Cost per mile traveled	0.40
Cost per mile hauled	0.80
Cost per ton-mile with a 5-ton load	0.16

The rate of travel will vary considerably in different sections of a large city, being slower through streets congested with a large volume of traffic. In such districts, the collection work may preferably be done at night or in the early morning.

Cost of Horse Maintenance in Boston, Mass.—The average cost in 1918 of maintaining the horses of the sewer and sanitary division of the Public Works Department of Boston, Mass., was $1.68 per day per horse, according to the recently issued annual report of the depart-

ment.* An average of 171.8 horses was kept. The itemized cost was as follows:

	Per horse per day
Labor	$0.5837
Hay and grain	.8355
Fuel	.0087
Light	.0056
Rent and taxes	.0500
Yard and stable repairs	.0187
Yard and stable furnishings	.0285
Veterinary services and medicine	.0225
Horseshoeing, etc.	.1292
Total	$1.68

D.—TRANSFER STATIONS

The building and operation of transfer stations should be considered as a part of the cost of transportation. A transfer station to handle 600 cu. yd., or 375 tons a day, has cost, depending on the type of building and local conditions, from $30,000 to $50,000, including land in a fairly well built-up section.

In 1916 the annual cost of operation, for about 375 tons per day, was estimated as follows:

Interest at 5%	$2500
Depreciation of plant at $2\frac{1}{2}$%	1250
Labor:	
1 foreman	1200
4 laborers	3600
Repairs and supplies	2500
Total	$11,050

This is equivalent to a cost of 9.5 cents per ton.

E.—TRANSPORTATION

The cost of transportation of refuse from the transfer station to the place of final disposal depends on the method used. The cost for each of several methods is discussed below. Chapter IV, under different subheadings, also contains information on the cost of supplemental transportation.

* *Engineering and Contracting*, March 3d, 1920.

1. By Trolley.—Having a typical transfer station receiving 600 cu. yd. of refuse material per day, and trains made up of one motor car, which carries no load, and two trailers, each trailer having a capacity of 25 cu. yd., then, 24 trailer loads are required to move 600 cu. yd. per day. If the place of disposal is in such a location that each train can make two trips a day, six trains will be required. Assume that three motors can handle the six trains. The daily cost of operation would then be:

Motor cost; three at	$25 =	$75 per day.
Trailers; twelve at	6 =	72 per day.
Total.		$147 per day.

If the 600 cy. yd. of refuse weigh 375 tons, the cost of trolley transportation would be 40 cents per ton.

2. By Barges.—A good serviceable tug has cost about $30,000, and deck-scows about $7000 each. The annual cost of operating a fleet may then be estimated as follows:

Annual Cost of Tug:		
Interest at 5%		$1,500
Depreciation on 15-year life		1,389
Labor:		
Captain	$2100	
Engineer	1800	
Fireman	1000	
Deck hands	1800	
		6,700
Repairs		2,500
Fuel		3,500
Supplies		1,000
Insurance		200
Total		$16,789

Annual Cost of Barge:		
Interest at 5%	$350	
Depreciation	324	
Deck hands	1,800	
	$2,474	
Assume that one tug serves four barges		$9,896
Total annual cost of fleet		$26,685

If each barge makes one trip per day, carrying 100 tons of refuse, the cost per ton amounts to 22 cents.

3. By Steam Railroads.—The cost of transportation by steam railroads depends principally on the switching charges. These may range from $5 to $15 per car. A car will hold about 40 tons of garbage, on which basis the switching charge will average about 25 cents per ton. Table 61 gives the cost of transporting garbage by steam railroad at Cleveland and Columbus, Ohio.

TABLE 61.—COSTS OF TRANSPORTING GARBAGE BY STEAM RAILROAD

City	Year	Population	Length of haul, in miles	Tons of garbage	Total cost	Cost per ton	Cost per ton-mile	Cost per capita
Cleveland, Ohio	1905	468,000	9	30,382	$4,561.00	$0.150	$0.017	$0.010
"	1910	560,663	9	44,747	6,260.00	0.140	0.015	0.011
"	1913	620,000	9	52,354	6,682.15	0.128	0.014	0.011
"	1919	770,000	9	60,932	11,441.86	0.188	0.021	0.015
Columbus, Ohio	1912	192,700	2	18,789	4,300.00	0.229	0.057	0.022

4. By Motor Trucks.—The cost of loading a motor truck is analyzed by the same method as mentioned for wagons. The cost for truck operation per hour will be greater than for wagons, and the rate of loading will have to be increased proportionately to make the cost equal to that of loading a horse-drawn wagon. The cost of haul by motor truck, however, will be less. The relatively high loading cost for motor trucks can be reduced by limiting them to transfer work and by using the so-called tractor and trailer system, being tried on a large scale in New York and other cities in America, and already used in quite a number of European cities.

The first cost of motor trucks varies with the kind of body, the general finish, the appurtenances, the motive power, and other items. In view of the present uncertainty of prices, no costs are here given. They can be readily ascertained at any time from dealers.

*The Electrical World** has compiled operating costs for electric motor trucks in commercial service from 50 plants in all parts of the United States. The costs include interest, depreciation, insurance, licenses, upkeep of tires, batteries, mechanical parts, power, supplies, garage charges, drivers' wages, and supervision. The daily mileage is not recorded, but the cost per day, for the various sizes, is given in the following table:

* October 7, 10, and 17, 1914.

Rated capacity, in tons	Average cost per day
0.5	$6.34
1.0	7.56
2.0	8.92
3.5	10.38
5.0	11.74

The Chicago Chamber of Commerce, in 1915, after compiling a large number of data for commercial trucks of various sizes, arrived at an average cost of operation of $0.11 per ton-mile, including fixed charges. These figures were quite representative when published, but at present might be multiplied by almost two.

In reference to the operating charges on gasoline motor trucks, the following is abstracted from an article by Mr. Joseph Husson, Editor of *The Commercial Vehicle*, in the issue of that journal of April 15, 1919, pp. 26–28.

The yearly charges for gasoline motor trucks are given below, their magnitude being in the order named.

The total yearly charges are nearly equal to the first cost of the truck, with its body, dumping device, and other accessories. Mr. Husson illustrates this by what he calls " The Big 8 in Truck Operation," giving the details of the yearly operation of a 5-ton Pierce-Arrow truck used in the general contracting business in Philadelphia. The original cost of this truck, including $400 for the body and $132 war tax on the truck, was $6032.

The costs of operation for one year (1918) were:

			Percentage
1. Driver's wages		$1560.00	29.9
2. Tires		1095.60	21.1
3. Gasoline	$693.16		
Oil, etc.	36.00	729.16	14.0
4. Inspection and repairs		399.60	7.6
5. Depreciation (life of 150,000 miles)		391.20	7.5
6. Insurance		377.38	7.3
7. Interest on investment at 6%		361.92	6.9
8. Garage		300.00	5.7
Totals		$5214.86	100.00

The total number of days operated was 300, and the mileage 12,000. The average daily mileage was 40. The cost per day operated was $17.38, and the cost per mile was $0.434.

The largest item in the operating costs is the driver's wages. Labor costs are high, and may yet increase before stabilizing. In operating the truck, much depends on the driver. If he is careless or indifferent, the resulting costs per ton-mile may be excessively high, even if the truck is one of the best on the market and is operated under the best possible conditions of loading and unloading.

The cost of the tires was $1095.60 for the 12,000 miles, or $0.0913 per mile, including depreciation, etc. The original cost of the four tires was $639.16, and they carried a guaranty of 7000 miles. This cost for tires is almost as large as that for the driver, and indicates that the greatest care should be taken in selecting them and keeping them in repair. Tire costs and loss of time when making tire changes are important, and should not be overlooked. Of course, the condition of the roads traversed affects the life of all tires, and the speed of the vehicle and the care or carelessness of the driver are most important factors. Overspeeding and overloading are the two greatest truck evils, and show their influence directly in tire costs. The manner of starting and stopping the truck also has an important influence on the wear of the tires.

The cost of gasoline is the third item in importance, which indicates that it should be reduced in every way possible. In general, the engine should not be allowed to run while the truck is standing and being loaded or unloaded. The engine starter has been used extensively on trucks having pneumatic tires, and has proved a great gasoline economizer; but it has not yet been found entirely practicable to use it on the larger trucks having solid tires.

Regarding the cost of inspection and repairs, it may be said that, in the case of the 5-ton Pierce-Arrow truck cited, this item was about $3\frac{1}{3}$ cents per mile. The best way to cut down this expense is to make repairs while they are small. This may be done by making a brief but thorough daily inspection. Excessive repair costs are generally due to overspeeding, overloading, or general carelessness on the part of the driver. Proper lubrication is also an important factor in reducing the cost of repairs, and efficient garage methods save the mechanic's time.

The depreciation charge is affected, to a large extent, by the initial cost of the chassis, body, and equipment of the truck. It has been customary to charge off this depreciation by assuming that the truck will last a certain number of years. A more rational method is to assume the truck to have a life of so many thousand miles, and to apportion the depreciation to cover this assumed life, considering the kind of work being done. In the case cited the truck was

assumed to have a life of 150,000 miles. This, however, seems to be too high for the average truck, unless the best of care is taken in operation and maintenance.

The item of insurance against fire, theft, and accident is almost as large as that of inspection and repairs. Insurance, however, is very important, and should never be neglected.

Interest is an item which is in direct proportion to the original cost of the chassis, body, and accessories, and in this case was computed at 6%, the legal rate in New York State.

The eighth and last item is the charge for garageing. In this the truck owner must decide whether it is more economical to maintain his trucks in a public garage or in one of his own. Generally five or more trucks can be maintained more cheaply in the owner's garage than in a public one.

A study of a number of records indicates that the daily mileage of trucks will generally range from 25 to 40.

The Chicago Civil Service Commission, after an extended study in 1912–13, found the operating cost of a 3-ton gasoline truck to be $0.13 per ton-mile. A 3-ton electric truck cost $0.11 per ton-mile, with current at 0.6 cent per kilowatt-hour, which, however, is a rather low figure for electric power, particularly since the report was made.

The Department of Public Works in Chicago uses one 5-ton and one 2-ton gasoline truck for delivering materials between city yards and construction jobs. The average cost of operating the 5-ton truck was 13 cents per ton-mile. The cost of operating the 2-ton truck varied from 14 to 32 cents per ton-mile. The cost by teams under contract was 26.9 cents per ton-mile. These figures are from actual service records kept during the last six months of 1914, and include fixed and all other charges. They are, however, only for truck operation, and do not include the wages of helpers for loading, etc.

Messrs. Downing and Perkins, of Hartford, Conn., reported in April, 1917, that the average cost per day for operating a 1-ton truck, with an average daily haul of 37.2 miles, and including driver's pay, depreciation, interest, and all other expenses, was $5.97.

The Waterbury Committee's investigation in 1919 showed that for twenty-five cities under municipal collection the average per capita cost of collection was $0.30; for fourteen cities of more than 125,000 population it was $0.26; and for eleven cities of less than 125,000 population it was $0.36. The average for five cities under the contract system was $0.36¼ per capita. Per capita costs were used in Waterbury, rather than per ton costs, because of the belief that the number of persons affected determines the number of col-

lection trips more accurately than the quantity collected, which may vary greatly in different districts.

Mr. Ralph W. Horne * gives a table, showing the complete average of operating costs of trucks, which we copy below. Items 1 to 5 are more or less constant, irrespective of ton-mileage. Items 6 to 9 decrease directly as the ton-mileage increases, indicating that, in a given period of time, as large a ton-mileage as possible should be accomplished.

" The table expresses the percentages which any given item is of the total time. They are based on a cost of 25c. per gallon for gasoline, taxes at $18 per $1000, license fees on the basis adopted by the Massachusetts Highway Commission, storage charges at the rate of $20 per month, and depreciation costs on the sinking-fund basis with interest at 5.5% applied annually. The life of the truck has been rationally estimated after careful study of the conditions under which the given truck was operating. Allowance must be made for any factors which may tend to increase or decrease the items, such as poor *vs.* good roads, hilly *vs.* level country, short *vs.* long haul, light *vs.* heavy loads, and short loading *vs.* long loading periods. An allowance likewise should be made where the costs of fuel, supplies, and labor differ greatly."

Operating Costs of Motor Trucks

"Capacity of truck, tons	2	3	$3\frac{1}{2}$	4	5	7
Average load carried, tons	2	3.3	3.8	4.15	5.2	6.5
Total operating cost, cents per ton-mile	21.5	19.0	18.1	17.8	16.5	15.0
Per cent of total cost per ton-mile of cost of:						
1. Gasoline	13.6	15.2	17.3	19.7	18.6	17.0
2. Lubricants	4.7	4.2	2.0	1.4	2.2	2.2
3. Tires	18.0	14.8	13.5	10.8	16.7	20.2
4. Repairs and sundries	9.1	9.4	10.0	10.5	11.0	11.1
5. Depreciation	23.5	22.0	20.5	21.0	20.0	20.0
6. Chauffeur	18.1	20.6	24.0	21.7	17.3	15.4
7. License, insurance, and taxes	4.3	4.4	4.6	5.4	5.0	4.8
8. Storage	5.2	4.8	3.0	3.6	3.7	4.0
9. Interest (at $5\frac{1}{2}$% per annum)	3.5	4.6	5.1	5.9	5.5	5.3

**Engineering News-Record*, Sept. 20, 1917.

F.—ACTUAL COSTS AVAILABLE

More actual data should be collected in order to verify the costs estimated herein, as but very few are now available, and as the war effects have materially modified them. The costs for collection service, as generally recorded, include both loading and hauling in one figure, but costs of transportation are frequently given separately. Some data from cities in which the itemized cost of collection is available have been summarized below.

1. New York.—The cost per cubic yard for the collection and removal of garbage, in steel carts having an average capacity of 2 cu. yd., in 1914, was 60½ cents per cubic yard in Manhattan and 67 cents in Brooklyn. For the collection of ashes and street sweepings the average cost was 59½ cents per cubic yard. Rubbish removal in 7.5-cu. yd. carts cost $0.216 per cubic yard. Although these figures take no account of the length of haul, they give a general idea of the unit cost of the service in 1914.

Parsons, in 1906, stated that garbage can be transported and dumped at sea in a Delahanty self-dumping scow for 19 cents per cubic yard, equivalent to about 35 cents per ton.

The following data are from a report by Mr. J. T. Fetherston on the operations in the Borough of Richmond in 1911:

	Quantities	Unit cost
Collection of street sweepings.......	36,210 cu. yd.	$0.35 per cu. yd.
Snow removal from roadways.......	42,190 "	0.19 " "
Cleaning gutters of snow and mud, by hand..........................	1,503.4 miles	4.72 per mile
Cleaning gutters of snow and mud, by plow..........................	49 "	0.56 " "
Cleaning snow from sidewalks.......	12.76 "	78.97 " "
Cleaning snow from cross-walks.....	262.2 "	6.52 " "

The reports of the Department of Street Cleaning, for the Boroughs of Manhattan, Brooklyn, and The Bronx, show that the cost of collection of street sweepings in 1918 was greater than in 1917 as the salaries of inspectors were increased from $100 to $115 per month, teams from 66⅔ cents to 75 cents per hour, and shovelers from 25 cents to 27 cents per hour.

The following items of expenditure have been taken from the report of the Department of Street Cleaning for 1917, and refer to the Boroughs of Manhattan, Brooklyn, and The Bronx, with a population of 5,241,302. The last column has been added to show the expenditure per 100,000 population.

	Total expenditure	Expenditure per 100,000 population
Salaries and wages, regular	$4,844,300	$92,425
Salaries and wages, temporary	781,500	14,914
Supplies	660,700	12,605
Equipment	201,500	3,844
Materials	131,100	2,501
Repairs and replacements	16,300	311
Transportation and telephone	143,100	2,730
Final disposition, department service	121,000	2,309
Final disposition, general plant service (contract)	1,194,000	22,781

The number of men engaged in the collection service and by the Department for the final disposition service, in the above three Boroughs, is as follows:

	Total number of employees	Number of employees per 100,000 population
Collection Division:		
Foremen and hostlers	251	4.79
Stablemen	212	4.04
Drivers	1956	37.32
Refuse collectors (Manhattan alone)	116	2.21
Final disposition (including street sweeping, but excluding disposal of garbage by contract):		
Superintendent, inspectors, and boardmen	120	2.30

In addition to the employees mentioned above, there was a suitable force of clerks and mechanics, and also the medical and surgical service.

2. Chicago.—A careful analysis of the cost of collecting garbage, ashes, and rubbish in Chicago is shown in Table 62, for the years 1908 to 1918.

TABLE 62.—AVERAGE COSTS OF COLLECTING REFUSE IN CHICAGO

(Loading and hauling)

Year	Cost per ton of garbage	Cost per cubic yard of ashes and rubbish	Year	Cost per ton of garbage	Cost per cubic yard of ashes and rubbish
1908	$3.78	$0.56	1914	$3.63	$0.66
1909	3.76	0.57	1915	3.20	0.70
1910	3.43	0.59	1916	3.70	0.72
1911	3.19	0.62	1917	4.35	0.76
1912	3.20	0.60	1918	4.79	0.86
1913	3.69	0.62			

If ashes and rubbish together weigh 1000 lb. per cubic yard, the cost of collection for these materials amounts to $1.20 per ton. Jacobs and Cenfield state that in Chicago:

"The Royal Lighterage Company has the contract for transportation from the loading stations, and the present contract is made on a per diem basis at the rate of $81.45 for each working day. During the year 1912 the cost of operation, maintenance, and lighterage of garbage delivered to the Oakley Avenue station averaged about 80 cents per ton. The cost of operation, maintenance, and lighterage chargeable against the garbage delivered to the Chicago Avenue loading station averaged about 65 cents per ton during the same period."

The cost of operating the hoist or of making the collections is not included.

Mr. George A. Zinn estimated the cost of team haul in Chicago in 1912 at 50 cents per ton-mile. (See also Chapter III, under Speed Rate.)

3. Philadelphia.—For Philadelphia conditions, a report in *Engineering News* of January 11, 1917, gives $17.91 as the cost of operating a 5-ton gasoline truck 50 miles per day. The fixed charges were $5.39 per day, or 30% of the total cost.

The variable expenses were:

	Per mile	Per day at 50 miles	Percentage of total cost per day
Depreciation*	$0.06	$3.14	17.6
Gasoline at 25 cents per gallon	0.083	4.17	23.3
Lubricating oil	0.006	0.27	1.5
Tires	0.039	1.94	10.8
Repairs	0.06	3.00	16.7
Totals	$0.25	$12.52	69.9

* About 15% of the first cost depreciates with the passage of time, and about 85% is proportional directly to the mileage run.

Assuming 25% as the depreciation for the life of the truck, operating 25 miles per day, with a life of 1500 days, we must explain that this rather high allowance is due to the following facts: That a truck used in house-to-house collection work must be started and stopped many times for each loading, that the motor must be kept running during the short stops, and, on account of the many stops and starts, the average speed will be much less than the most economical speed of the truck. We should also note the deleterious effect on the truck of the dust from the street and the grit and ashes of the refuse.

4. Cleveland.—The work of collecting garbage is carried on by the Garbage Disposal Division of the Department of Public Service. A superintendent of garbage collection is in direct charge of the work.

The garbage wagons are built according to specifications drawn by the city. They consist of a water-tight, steel body, on a four-wheeled running gear. The body is arranged to dump at the rear, and has a canvas cover. The capacity of a wagon is 70 cu. ft. One horse and one man go with each wagon.

Garbage collections are made every other day in districts within $1\frac{1}{2}$ miles of the loading station, and every third day in outlying districts. No collections are made on Sundays. About 100 wagons are used to collect from the entire city.

The wagons deliver the garbage to a central loading station on the Baltimore and Ohio Railroad. Special garbage cars are used to transport the garbage from the loading station to the reduction plant, 9 miles distant.

Table 63, giving the cost of collection of garbage for 1919, was taken from the annual report of the department. This table also gives a summary of costs for 1913 to 1919.

TABLE 63.—COST PER TON FOR COLLECTING GARBAGE IN CLEVELAND FOR THE YEAR ENDING DECEMBER 31, 1919; AND SUMMARIES FOR 1913 TO 1919, INCLUSIVE

(From Department of Public Works)

(Quantity of garbage collected in 1919 = 60,932 tons)

Supervision		$0.0375
Operation: Labor for collecting		4.0862
Labor for shoeing		0.0902
Supplies: Office		0.0039
Fuel, light, and power		0.0228
Feed		0.4984
Shoeing		0.0414
Barn		0.0378
Motor vehicles		0.0795
Cleaning and toilet		0.0009
Medical and surgical		0.0042
Miscellaneous		0.0030
Overhead and miscellaneous		0.0675
Maintenance:		
Cars and wagons, labor and material		0.3352
Harness, labor and material		0.0716
Buildings, labor and material		0.0667
Office furniture and fixtures		0.0010
Machinery, tools and implements		0.0055
Motor vehicles		0.0219
Miscellaneous equipment		0.0343
Total collection cost		$5.5095
Loss on horses		0.0172
Depreciation		0.1148
Total collection cost including depreciation	$343,748.84	$5.6415
Cost of supplemental transportation from Canal Road to Willow	11,426.06	0.1875
Total cost of city collection and supplemental transportation to Willow	$355,174.90	$5.8290

Year	Total cost	Cost per ton	Cost per capita
1913	$124,938.26	$2.385	$0.2016
1914	165,658.52	2.98	0.221
1915	181,556.29	2.91	0.276
1916	195,266.18	3.22	0.290
1917	236,035.16	4.21	0.341
1918	304,183.38	5.27	0.430
1919	355,174.90	5.83	0.461

The following is a statement of the cost, etc., of the collection plant at Cleveland in 1919:

Building at Canal Road	$815.00
Equipment:	
Furniture and fixtures	541.40
Cars and wagons	28,040.00
Harness	3,165.00
Horses and mules	22,715.00
Motor vehicles	4,260.00
Miscellaneous	4,653.52
Inventory:	
Supplies	4,976.55
Maintenance	1,170.14
Total value	$70,336.61

5. Baltimore.—Table 64 shows the cost of collecting the mixture of garbage, ashes, and rubbish in Baltimore for 1913.

TABLE 64.—COST OF COLLECTION OF MIXED REFUSE IN BALTIMORE, IN 1913

	Total cost	Cost per ton
Pay-roll	$150,029.88	$0.465
Feed	36,866.63	0.114
Shoeing	4,167.62	0.013
Stable rent	1,350.00	0.004
Veterinary	552.48	0.002
Sundries	2,028.37	0.006
Wagon and cart repairs	4,949.01	0.015
New carts	5,043.00	0.016
Horses and mules	15,025.00	0.047
Harness	1,102.78	0.003
Totals	$221,114.77	$0.685
	Cubic yards	**Tons**
Garbage	180,531	90,270
Ashes and rubbish	464,720	232,360
Total tons		322,630

6. Detroit.—The garbage is collected by the city. The wagons comprise a water-tight steel body on a four-wheeled running gear.

The body is removable, and is transported to the reduction plant on freight cars. Each wagon is drawn by one horse, and is served by one man. The cost of collection per ton for 1910 is shown in Table 65, which also gives a summary for 1910 to 1916, inclusive.

TABLE 65.—COST OF GARBAGE COLLECTION IN DETROIT, MICH., IN 1910; AND SUMMARIES FOR 1912 TO 1916, INCLUSIVE

(Population in 1910 = 465,766, tonnage = 34,065)

	Total cost	Cost per ton	Percentage
Operating expense:			
Labor	$46,813.05	$1.374	68.2
Feed, and shoeing 65 horses	11,221.29	0.329	16.3
Supt., ass't clerk, and blacksmith	3,971.00	0.117	5.8
Maintenance—Wagons	2,082.00	0.061	3.0
Maintenance—Harness	220.00	0.006	0.3
Fire insurance for horses and equipment	249.99	0.007	0.4
Stable supplies, telephone, fuel, etc	704.43	0.021	1.0
Services of veterinary	221.95	0.007	0.3
Horses replaced	2,775.00	0.082	4.0
Sundries, scoop shovels, etc	182.76	0.005	0.3
Maintenance—Buildings	298.93	0.009	0.4
Totals	$68,740.40	$2.018	100.0
Depreciation of equipment	$2,856.34	$0.084	

	Total cost	Cost per ton	Cost per capita
1910	$68,740.40	$2.018	$0.147
1912	94,404.45	......	0.194
1913	102,132.30	2.17	0.202
1914	122,317.44	2.14	0.235
1915	133,529.60	1.91	0.248
1916	145,899.42	1.88	0.263

7. Milwaukee.—In Milwaukee, all refuse is collected under the supervision of the Department of Public Works. Two separations of the refuse are made, the garbage being collected alone and the ashes and rubbish together.

The garbage is collected in four-wheeled wagons with removable iron bodies of 1.5 cu. yd. capacity. They are drawn by one horse, and one man goes with each wagon. The city furnishes the iron bodies,

but does not own the vehicles or horses. The price paid per day for a horse, vehicle, and collector is $3.50.

The garbage collections are made in the early morning, on five days a week during the winter and six days a week during the summer. Each collector brings two loads per day to the incinerator, and the wagons are routed so that one load has a short and the other a long haul.

At the incinerator, a crane picks up the wagon body, dumps the garbage into storage bins, and replaces the empty body on the wagon.

The ash and rubbish collection is made with 3-yd., bottom-dumping, wooden wagons, drawn by two horses. The wagons, horses, and drivers are hired by the city. Collections are made once or twice a week. In collecting the ashes and rubbish, the driver has no helper assigned to him, but in each ward there is a crew of men whose duty it is to help load all wagons in the ward.

Tables 66 and 67, computed from the reports of the Department of Public Works, give the cost of this collection service.

TABLE 66.—ANNUAL COST OF COLLECTION OF GARBAGE IN MILWAUKEE

For year ending December 31st	Items	Total cost	Cost per ton	Cost per capita	Percentage of total cost
1914	Superintendent	$ 1,200.00	$0.030	$0.0028‡	1.030
	Timekeeper	936.29	0.024	0.0022	0.803
	Stationery, etc	5.50	0.0001	0.00001	0.005
	General supplies	64.41	0.002	0.0002	0.055
	General repairs	32.75	0.001	0.0001	0.028
	Telephone	99.00	0.002	0.0002	0.085
	Horse and vehicle hire	113,453.25	2.869	0.2701	97.365
	Street car fare	72.75	0.002	0.0002	0.062
	General equipment	660.18	0.017	0.0016	0.567
	Totals	$116,524.13	$2.947*	$0.2774	100.000
1916	Salaries	$2,028.71	$0.053	$0.0046	1.697
	Supplies	328.50	0.009	0.0007	0.274
	Horse and vehicle hire	117,210.17	3.078	0.2665	97.898
	Equipment, horse-drawn vehicles	106.25	0.004	0.0004	0.131
	Totals	$119,723.63	$3.144†	$0.2722§	100.000

In 1918 the average cost of garbage collections was $4.83 per ton. It has increased gradually since 1913, when it was $2.42 per ton. The wages paid to the collectors in 1918 were $4.50 per day, and each collector was required to bring in two loads a day.

* 39,543.51 tons of garbage collected during 1914.

† 38,139 tons of garbage collected during 1916.

‡ Population in 1914 estimated at 420,000.

§ Population in 1916 estimated at 440,000.

FIG. 67.—ANNUAL COST OF COLLECTION OF ASHES AND RUBBISH IN MILWAUKEE

For year ending December 31st	Items	Total cost	Cost per ton*	Cost per cubic yard†	Cost per capita‡	Percentage of total cost
1914	Labor	$94,361.90	$6.6391	$0.2933	$0.2247	42.78
	General supplies	431.38	0.0029	0.0013	0.0010	0.20
	General repairs	8.25	0.0001	0.00002	0.00002	0.004
	Horse and vehicle hire	125,428.93	0.8495	0.3899	0.2986	56.86
	General equipment	358.36	0.0024	0.0011	0.0007	0.16
	Totals	$220,588.82	$1.4940	$0.6856	$0.5250	100.00
1916	Labor	$98,212.82	$0.6430	$0.2945	$0.2233	44.00
	General supplies	368.09	0.0024	0.0011	0.0008	0.17
	Horse and vehicle hire	124,490.90	0.8150	0.3738	0.2830	55.83
	Totals	$223,071.81	$1.4604	$0.6694	$0.5071	100.00

In 1918 the average cost of collection of ashes and rubbish was $0.79 per cubic yard.
* 147,640 tons collected during 1914.
152,800 tons collected during 1916.
† 321,669 cu. yd. collected during 1914.
333,375 cu. yd. collected during 1916.
‡ Population in 1914 estimated at 420,000.
Population in 1916 estimated at 440,000.

Table 68 gives the tonnage of garbage, the volume of ashes and rubbish, and the costs for labor and team haul, for each month of 1919, together with some comparative figures for 1918 and 1917.

Prior to 1910, garbage was transported across the Milwaukee River by barge. The wagon bodies were hoisted to the deck of a barge which made two trips a day. The towing service was given free by the fire tug. The cost of hoisting and transportation ranged from 12 to 15 cents per ton.

8. Washington.—In Washington, the work is done by contract, and certain fines are deducted, in accordance with the specifications. Summaries of additional cost data, taken from annual departmental reports, are shown in Table 69.

9. Columbus.—The following notes on collection, compiled from various sources, apply to the year 1912, for which the costs are given.

The collection of all refuse is carried on by the city under the supervision of the Department of Public Service, with the Superintendent of the Department in direct charge of the work.

Two separations of refuse are made. The garbage is collected by itself and delivered at a loading station near the center of the city.

Rubbish is collected and hauled to dumps. Due to the general use of natural gas, there is very little ash, and this is collected with the rubbish.

Table 68.—Unit Costs of Collection, in Milwaukee, in 1919

Month	Garbage		Ashes and Rubbish	
	Number of tons	Cost of Labor and team haul per ton	Number of cubic yards	Cost of Labor and team haul per cubic yard
January	2,272	$6.08	59,895	$0 94
February	1,617	6.27	44,236	0.95
March	1,924	6.00	45,024	0.94
April	2,085	5.87	40,441	0.89
May	2,380	5.91	34,022	0.82
June	2,899	5.39	24,839	0.97
July	3,409	5.12	11,226	1.02
August	3,679	4.63	9,994	1.05
September	3,604	4.68	10,098	0.55
October	3,417	5.00	22,901	1.05
November	2,528	5.45	33,769	1.00
December	2,236	6.42	58,420	0.96
Totals, 1919	32,050	......	394,865	......
Averages	......	$5.43	......	$0.94
Totals for 1918	......	$4.83	356,786	$0.79
Totals for 1917	......	4.18	366,120	0.70

Average weight of one load of garbage = 913 lb. Two loads a day for each team. Wages $5.00 per day.

The garbage wagons have a capacity of 2.5 cu. yd., and are specially built according to the city's specifications. They consist of a rectangular steel body mounted on heavy running gear and provided with a spring seat. The cover is of canvas, put on in sections, which makes it possible to uncover only a part of the wagon at a time. Two horses and one man go with each wagon.

The garbage collection work is carried on during six days per week. From January 1st to July 1st garbage is collected once each week; from July 1st to October 1st, twice each week; and from October 1st

TABLE 69.—DATA RELATING TO COLLECTION OF ALL CITY WASTES, FROM 1910 TO 1916, IN WASHINGTON, D. C.

	1910	1911	1912	1913	1914	1915	1916
NUMBER OF UNITS COLLECTED:							
Garbage....tons	44,236	48,214	47,445	50,778	48,927	50,806	52,207
Ashes....cubic yards	162,272	171,361	203,568	200,430	255,358	148,190	135,305
Miscellaneous refuse..cubic yards	72,060	108,789	115,378	138,382	140,683	146,152	157,180
Night-soil....barrels	26,280	23,834	21,266	19,895	15,514	12,949	12,741
Dead animals....number	18,875	16,720	17,492	21,287	19,148	20,570	22,724
TOTAL NET COST:							
Garbage....	$78,396.00	$68,400.00	$68,384.00	$68,388.00	$68,384.00	$68,374.00	$69,788.00
Ashes....	65,852.40	73,111.00	73,053.00	73,129.00	73,007.00	73,041.00	68,935.00
Miscellaneous refuse....	15,654.00	14,934.00	16,560.00	16,593.00	16,583.50	16,609.00	28,187.00
Night-soil....	15,984.00	16,272.00	16,600.00	16,600.00	14,962.00	14,996.00	14,990.00
Dead animals....	2,360.80	2,855.00	2,855.00	2,855.00	2,853.00	2,855.00	2,988.00
COST PER UNIT:							
Garbage....per ton	$1.77	$1.41	$1.44	$1.34	$1.39	$1.34	$1.34
Ashes....per cubic yard	0.40	0.42	0.36	0.36	0.29	0.49	0.51
Miscellaneous refuse..per cu. yd.	0.21	0.14	0.14	0.12	0.12	0.11	0.18
Night-soil....per barrel	0.60	0.68	0.78	0.83	0.96	1.16	1.17
Dead animals....each	0.126	0.170	0.163	0.134	0.149	0.14	0.13
FINES DEDUCTED:							
Garbage....	$4.00	....	$16.00	$12.00	$16.00	$26.00	$52.00
Ashes....	192.00	$39.00	97.00	21.00	143.00	109.00	65.00
Miscellaneous refuse....	346.00	2,066.00	440.00	407.00	416.50	391.00	213.00
Night-soil....	516.00	328.00	....	....	38.00	4.00	10.00
Dead animals....	....	....	....	....	2.00	....	....

to December 31st, once each week. This schedule is not followed in the down-town district, where collections are made daily. The average number of teams at work each week is as follows: January to July, 18; July to October, 24; October to December 31st, 18. The city is laid out in 18 routes, each being divided into two sections. One section is a long haul from the loading station and the other a short haul. These are grouped as far as possible so as to give each team an equal number of miles to travel per day. By this method no team travels more than 16 miles daily. Each team collects two loads daily, except the hotel team, which collects from three to five. The loads must average $1\frac{1}{2}$ tons. The average haul is 4 miles.

The rubbish wagons are four-wheeled, with wooden bodies of 3 cu. yd. capacity. They are drawn by two horses.

For the collection of rubbish, the city is divided into eight districts, each being in charge of a foreman, who has control over about four teams, four drivers, and one helper. The number of teams working daily, throughout the year, averages 35. The number of loads each team hauls varies with the length of haul, but each must collect at least three loads daily. The average length of haul is 2 miles.

The garbage is transported from the loading station to the reduction plant by rail. Special cars, with a capacity of 80,000 lb. and holding about 1400 cu. ft., are used. By means of a siding at the reduction plant and another at the loading station, the cars are hauled directly from one to the other, a distance of about 2 miles.

Table 70 gives the first cost of the collection and transportation equipment. Table 71, computed from figures in the reports of the Department of Public Service, gives the cost of collection, exclusive of fixed charges, of the different classes of refuse.

The cost of collecting manure in Columbus in 1917 and 1918 was as follows:

Year	Tons collected	Cost of collection	Cost per ton	Revenue	Profit
1917	2504	$3462.64	$1.38	$3480.00	$17.36
1918	2908	3880.97	1.33	4049.00	168.03

10. Toronto.—In Toronto, in 1919, Osborn estimated the cost of motor transportation for garbage and ashes at 14.0 cents per ton-mile for a full load and at 23.5 cents per ton-mile for a part load. These estimates were based on a length of route of 40 miles per day.

11. Trenton.—Table 72 gives the cost of collecting garbage and ashes in Trenton, N. J., from March, 1912, to March, 1913, and a summary of the cost for subsequent years up to and including 1918.

12. Sewickley.—Table 73 is taken from an account of garbage collection and incineration in Sewickley by the Borough Engineer, Mr. Edward E. Duff, Jr.*

TABLE 70.—COST OF EQUIPMENT FOR COLLECTION AND TRANSPORTATION OF REFUSE IN COLUMBUS, 1912

(Population estimated at 192,700)

	Total cost	Cost per capita
Loading station site	$ 10,136.40	$0.043
Loading station	14,101.64	0.073
Collection stables	42,260.81	0.219
Trestle and driveway	2,153.10	0.011
Grading, fill, electric wiring	2,379.54	0.012
Railway siding	3,161.60	0.016
4 garbage cars	7,564.00	0.039
34 garbage wagons	7,151.10	0.037
24 rubbish wagons	3,466.50	0.018
5 special rubbish wagons	1,625.00	0.003
Horses	24,000.00	0.125
Harness and stable supplies	5,484.31	0.028
Office equipment	522.51	0.003
Steel lockers	310.00	0.002
Totals	$123,316.51	$0.639

13. Calgary.—Table 74 gives the costs and other particulars for electric trucks of several sizes, at Calgary, during 1914.

14. Toledo.—Table 75 gives the cost of garbage collection in Toledo, Ohio, in 1918 and 1919. The collection is organized under the Street Cleaning Department. The city is divided into three main districts, each in charge of a superintendent. There are 28 wagon districts, each generally served by one man and a 2-horse wagon of 3 cu. yd. capacity. The wagons generally take one load a day. In a few districts the wagons have two men and take two loads a day.

15. Los Angeles.—In 1917–18 the cost of collection with $2\frac{1}{2}$-ton trucks on long hauls was $2.76 per ton, and using teams on short hauls was $2.00 per ton. The long hauls are from 6 to 9 miles; the

*Municipal Journal, November 11, 1915.

TABLE 71.—COST OF COLLECTION OF GARBAGE AND RUBBISH IN COLUMBUS, FOR YEAR ENDING DECEMBER 31, 1912

	Collection of Garbage				Collection of Rubbish				
	Total cost	Cost per ton *	Cost per capita	Percentage of total cost	Total cost	Cost per ton †	Cost per yard ‡	Cost per capita	Percentage of total cost
Teams and labor	$27,713.55	$1.476	$0.144	91.0	$42,117.52	$7.481	$0.561	$0.218	88.0
Superintendent, inspection, etc.	1,912.94	0.102	0.010	6.3	3,507.07	0.623	0.047	0.018	7.2
Repairs and miscellaneous	822.74	0.044	0.004	2.7	2,262.53	0.401	0.030	0.012	4.8
Totals for 1912	$30,449.23	$1.622	$0.158	100.0	$47,887.12	$8.505	$0.638	$0.248	100.0
Totals for 1917	$49,061.55	$2.772	$0.223	....	$73,292.37	$5.64	$0.421	$0.333	....
Totals for 1918	58,254.06	3.633	0.254	....	87,492.37	6.91	0.516	0.389	....

* Total tonnage for 1912 = 18,789.4. Estimated population, 192,700.
† Total production in 1912 = 750,960 yd. ‡ Computed from volume (1 cu. yd. = 150 lb.)

average is 8 miles. The operating cost of the trucks ranged from $210 to $250 per month, including fuel, wages, repairs, and depreciation, but not the wages of the two garbage collectors who accompany the truck. The trucks haul $2\frac{3}{4}$ tons per load, and make at least two trips per day.

Table 72.—Cost of Collecting Garbage and Ashes in Trenton, N. J, March, 1912, to March, 1913; and also a Summary for 1914 to 1918, Inclusive

	Garbage *			Ashes †		
	Total cost	Cost per ton	Percentage	Total cost	Cost per ton	Percentage
Labor	$6,819.83	$0.528	47.9	$6,372.01	$0.166	48.2
Feed	4,129.61	0.319	29.2	3,493.93	0.091	26.6
Horses	290.00	0.022	2.0	290.00	0.008	2.2
Harness and repairs	288.99	0.022	2.0	270.66	0.007	2.1
Wagons and repairs	1,328.15	0.103	9.4	1,250.35	0.032	9.5
Veterinary and drugs	32.75	0.003	0.2	34.40	0.001	0.3
Horse shoeing	515.00	0.039	3.6	543.02	0.014	4.1
Light	30.27	0.002	0.2	24.63	0.001	0.2
Repairs, plant and buildings	179.07	0.014	1.3	179.07	0.005	1.4
Miscellaneous	578.48	0.045	4.1	574.63	0.015	4.4
Supplies	12.13	0.001	0.1	......	....	....
Team hire	......	....	...	138.00	0.004	1.0
Totals	$14,204.28	$1.098	100.0	$13,175.97	$0.344	100.0
Totals for years ending March 31st:						
1914	$13,437.37	$0.94	....	$17,863.02	$0.46	....
1915	13,340.34	0.94	....	18,360.14	0.44	....
1916	14,679.92	0.99	....	18,727.47	0.42	....
1917	17,193.13	1.07	....	20,881.67	0.45	....
1918	21,935.09	1.45	....	29,523.16	0.61	....

* Total tonnage of garbage in 1913 = 12,930.
† Total tonnage of ashes in 1913 = 38,470.

Rubbish is collected at a cost of 96 cents per cubic yard. In the short-haul zone the collection was made with teams, with day and night shifts. The day shift collected 2200 tons per month at a cost of $2.15 per ton; the night shift collected 2800 tons per month at a cost of $1.18 per ton.*

* From *Engineering and Contracting*, September 11, 1918

TABLE 73.—COST OF COLLECTION OF GARBAGE IN SEWICKLEY, PA.; AVERAGE YEARLY CHARGE, MARCH 1, 1910, TO DECEMBER 31, 1914

	Total cost	Cost per capita
Labor	$1432	$0.286
Horse feed	400	0.080
Blacksmith	124	0.025
Insurance	37	0.007
Cans	440	0.088
Miscellaneous	50	0.010
Totals	$2483	$0.496

TABLE 74.—AVERAGE OPERATING COSTS AND FIXED CHARGES FOR TWO 1-TON, TWO 3-TON, AND TWO 5-TON ELECTRIC TRUCKS AT CALGARY, ALBERTA

Data for 1914

Items	Two 1-ton trucks	Two 3-ton trucks	Two 5-ton trucks	Monthly average cost per vehicle
Supplies	$0.50	$0.65	$0.75	$0.63
Repairs	30.05	91.14	191.14	104.11
Energy	11.83	15.71	33.19	20.24
Garage	10.00	10.00	10.00	10.00
Garage employees	28.75	37.75	42.75	36.42
Driver's wages	77.80	85.80	80.00	81.20
Interest, sinking fund, and depreciation	50.83	68.23	88.54	69.20
Storage battery department	14.58	23.61	27.78	21.99
Average cost per month	216.08	271.46	258.99	248.84
Average number of days in service per month	26	25.5	26	.....
Average number of miles per month	722.5	543.5	539.5	.....
Months in service during the year	9	9	9	.....

The cost for collection depends on a number of local factors, such as character of refuse material, climate, frequency of collection, length of haul, and size of wagon. The costs per ton for loading and hauling various refuse materials, for various methods of transportation, and for transfer stations, average approximately as shown in Table 76.

The figures in Table 76 are intended to give only roughly approximate costs before the War, and should not be applied to any particular local situation without careful reconsideration. A special study is required in order to estimate the cost for each locality, but the information contained in this chapter may be of material assistance for the preliminaries of a specific case.

TABLE 75.—ANNUAL COST OF GARBAGE COLLECTION IN TOLEDO, OHIO, AS SHOWN BY CITY REPORTS

	1918	1919
Supervision	$ 3,225.63	$ 5,127.51
Labor, collecting	40,310.14	50,770.24
Miscellaneous supplies	1,725.27	1,001.00
Horse-shoeing	....	2,658.65
Blacksmith and wagon repairs	1,571.30	2,127.90
Barn $\frac{60}{94}$ of $41,609.87	26,600.00	....
Barn $\frac{60}{100}$ of $50,378.95	....	35,257.37
Collection	$73,432.34	$96,942.67
Tons collected	20,320	19,990
Cost per ton for collection	$3.61	$4.87
Average length of haul	4 miles	4 miles
Cost per ton-mile for collection	$0.90	$1.22

This table includes no allowance for fixed or general overhead charges.

TABLE 76.—COSTS OF LOADING AND TEAM HAUL, TRANSPORTATION, AND TRANSFER STATIONS

Data for 1914

		Cost per ton
Loading and team haul:	Garbage	$1.00 to $3.50
	Ashes	1.00 to 2.30
	Rubbish	2.00 to 6.50
	Manure	1.50 to 2.50
	Mixed refuse	1.00 to 3.00
Transportation:	Street railway	0.30 to 0.50
	Steam railway	0.10 to 0.25
	Barge	0.20 to 0.40
	Motor truck	0.15 to 0.30
Transfer stations: Cost of operation		0.10 to 0.20

16. Paterson.—The costs of collection in Paterson, N. J., in 1920, exclusive of overhead charges, were approximately as follows:

	Yardage	Cost per cubic yard
Electric trucks	51,026	53 cents
Gasoline trucks	16,383	58 "
Horse wagons	86,270	74 "

G.—PRIVATE COLLECTION COSTS

Private scavengers are more often found in small than in large cities. In the latter the cost of collection to the individual served is generally greater than when the municipality does the work. Costs of private collections of garbage in several Ohio cities were stated to have been as low as 10 cents per family per week. In small residential towns in Illinois, the cost of collecting garbage by scavengers varies from $1 to $4 per family per month. In some instances, the removal of ashes is included in this figure.

H.—IMPROVED RECORDS DESIRABLE

The recording of unit cost data for loading, hauling, transferring, and transporting refuse materials, is of sufficient value to merit more attention by city officials than is now usually given. More records should be kept and more information published in the annual reports, so that useful comparisons may be made and a check secured on the efficiency of local work. The costs should be kept and recorded in as much detail as practicable, in order to cover each element of the work, and also the work done, if possible in man-hours and ton-miles. A suggested standard form for cost statistics has been published by the American Public Health Association and the American Society for Municipal Improvements, and is reproduced at the end of this chapter.

I.—SUMMARY AND CONCLUSIONS

In order to make a fair estimate of the cost of collecting and delivering refuse, we must consider all the various parts of the work. We should first know what is necessary to load the wagon properly, under the conditions existing in the specific town; and this will vary chiefly with the season, with the cost of apparatus, the location of the can, and the cost of labor. We should then estimate the work of hauling, which varies with the kind of wagons or trucks used, whether horse-drawn or motor-driven, and with the length of haul. The cost

will depend also on the rate of travel, influenced by the grade of the territory and the character and paving of the streets, and on the cost of the team and driver, or of the motor and mechanic.

The cost of transportation from the transfer stations to the points of final disposal depends on the particular method adopted and the distance to which the refuse is to be transported. These methods are: Conveyance by trolley, barge, steam railroad, or motor truck. Detailed estimates should be made of several of the most available means of transportation, in order to discover the most economical one.

As the collection of city refuse is sometimes the most expensive part of the refuse removal problem, it is quite important to make these cost estimates in as much detail as practicable. The selection of the most economical method of final disposal, as will be shown in Chapter XIII, may depend on the cost of collection and transportation.

Although the data in this chapter will help in making estimates, the recent large increases in the cost of labor and materials requires special caution in adjusting the prices prevailing before the War to those relating to present conditions.

As an aid to judge of the probable costs, we add Table 77, which gives the cost data in a number of American cities and for various years from 1910 to 1920. The information is given for mixed refuse and garbage separately, and for ashes and rubbish, both mixed and separated.

We wish here again to emphasize the desirability of recording information which allows the cost to be estimated independently of wages and team hire, and therefore, of the variations both in the wages and in the length of working days. This is done by recording the efficiency of the labor through time and work elements. In other words, when we record the ton-miles per hour for hauling by various means, both when collecting and delivering for final disposal, we shall be able, not only to compare the efficiencies under different organizations and conditions and by different means, but also to make safer estimates of cost, merely by multiplying the hourly cost of labor, prevailing at the time when the estimates are made, by such factors. We have endeavored to give such figures where they have been available.

TABLE 77.—COST OF COLLECTING REFUSE MATERIALS IN AMERICAN CITIES

City	Year	Population	Total tonnage	Total yardage	Approximate haul in, miles	Total cost	Cost per			
							Capita	Ton	Yard	Ton-mile
GARBAGE										
Boston, Mass.[1]	1916–17	762,256	45,615	....	....	$161,671.72	$0.34	$3.54	....	....
" "[2]	1919	491,111	36,583	62,005	1.10	170,168.47	0.25	4.65	$2.74	$4.23
" "[3]	1919	156,732	10,034	17,007	....	23,100.65	0.15	2.31	1.36	....
" "[4]	1919	146,973	10,219	17,320	1.50	60,484.64	0.41	5.92	3.49	3.95
Chicago, Ill.	1917	2,547,941	95,032	....	....	364,444.45	0.14	3.83	....	....
Cleveland, Ohio	1918	710,445	57,754	....	3	293,338.29	0.41	5.08	....	1.69
" "	1919	770,000	60,932	....	3	343,733.04	0.45	5.64	....	1.88
Columbus, Ohio	1918	226,000	15,630	....	....	58,254.06	0.26	3.63	....	....
" "[5]	1918	238,000	18,126	....	2.5	66,971.10	0.28	3.69	....	1.48
Dayton, Ohio	1916	127,224	16,334	....	....	25,207.00	0.20	1.54	....	....
Detroit, Mich.	1915–16	554,717	77,805	....	....	145,899.42	0.26	1.88	....	....
Evanston, Ill.	1910	24,978	2,800	....	....	3,186.00	0.13	1.14	....	....
Grand Rapids, Mich.	1919–20	140,000	8,600	....	....	49,352.46	0.35	5.70	....	....
Los Angeles, Cal.	1915–16	554,000	....	....	....	110,002.38	0.21	1.97	....	....
" " "	1918–19	543,000	44,011	....	4.5	137,996.69	0.25	3.14	....	0.70
" " "[6]	1919–20	575,000	51,789	....	4.5	165,958.14	0.29	3.20	....	0.71
Milwaukee, Wis.	1916	440,000	38,139	....	....	119,723.63	0.27	3.41	....	....
" "	1917	450,000	30,975	....	....	129,378.00	0.29	4.11	....	....
" "	1919	....	32,050	....	....	174,005.00	....	5.43	....	....
New Haven, Conn.[7]	1918	146,340	121,100 35,000 families and 114 hotels and restaurants	16,670	3.5	50,154.00	0.34	4.14	3.01	1.18

New York, N.Y.	1910	4,406,000	336,984	....	....	275,380.00	0.06	0.82	....	....
Pittsburgh, Pa.	1917	571,800(est.)	83,008	....	....	......	....	2.25	....	....
" "	1919	582,600(est.)	76,452	....	....	....	....	4.00[8]	....	....
Providence, R. I.	1919	272,000[9]	30,000[9]	....	0.8[9]	48,000.00[9]	0.18	1.60	....	2.00
Rochester, N. Y.	1917	264,714	25,949	....	....	32,870.25	0.12	1.27	....	....
St. Louis, Mo.[10]	1915	[11]746,000	48,620	....	3	....	....	....	....	....
" "	1916	757,300	46,636	....	3	....	....	....	....	....
" "	1917	[11]768,600	39,711	....	3	....	....	....	....	....
" "	1918	[11]770,270	34,775	....	3	....	....	....	....	....
" "	1919	771,930	34,469	....	3	....	....	6.61	....	....
" "	1920	773,600 (census)	....	....	....	....	....	....	....	....
Spokane, Wash.	1919	104,000	713.9[12]	....	6.25	6,145.20	....	8.70	....	1.39
" "	1919		957.8[13]	....	4.25	4,608.90	....	4.35	....	0.95
Washington, D. C.	1916	363,980	52,207	....	....	69,788.00	0.19	1.34	....	....
" "	1919–20	437,000	52,868	79,389	3.0	208,951.00	0.48	3.95	2.63	1.31

[1] Population served is 470,991, which is basis for per capita computation.

[2] Garbage collected by city forces within the city limits.

[3] Garbage collected and delivered to contractor for disposal of refuse collected by department force.

[4] Garbage collected by contract and disposed of by Boston Development and Sanitary Company.

[5] Garbage collected twice a week in summer; once a week for remainder of year; 22 garbage routes; 25 teams (average) collecting garbage. Average cost of feeding each horse, $0.75 per day. Average cost of caring for each horse, $1.25 per day.

[6] These figures for 1918–19 and 1919–20 are for garbage only (no rubbish) and are for the main city, excluding San Pedro, Wilmington, and San Fernando Valley. The population for 1918–19 is estimated, but that for 1919–20 is from the U. S. Census.

[7] Garbage collected from "back yards" of all residents once in 5 days (average) and from hotels and restaurants tri-weekly. Collection by city teams and men. Garbage taken to piggery at city poor farm. These figures are for collection only. The net cost was $21,537.47, or $0.15 per capita for collection and disposal. Garbage used also as fertilizer for truck farms.

[8] Contract prices.

[9] All approximate figures. Since May 1, 1920, the contractor has been paid at the rate of $104,000 per annum.

[10] St. Louis collects only garbage. Wagons average two loads per day. Cost of operating one wagon per day about $8.00. Collections daily in business district, and three times a week in other parts of city. City does not collect all the garbage; part is collected by licensed men. (Letter from R. C. Gans, Engineer).

[11] Interpolated figures.

[12] Residence district.

[13] Business district. Only about one-thirtieth of population has regular waste collection service.

TABLE 77.—COST OF COLLECTING REFUSE MATERIALS IN AMERICAN CITIES (*Continued*)

City	Year	Population	Total tonnage	Total yardage	Approximate haul, in miles	Total cost	Cost per			
							Capita	Ton	Yard	Ton-mile
Garbage and Rubbish										
Berkeley, Cal.[14]	1919–20	65,000	8,675	....	3	$52,000(est.)	$0.80	$6.00	....	$2.00
Houston, Tex.[15]	1919	165,000	38,606	....	1.25	55,000.00	0.33	1.43	....	1.14
London, Ont[16]	1918	50,640 12,830 houses; total population = 58,000	7,970	25,480 625.58 lb. per cu. yd.	2.25	18,500.00	0.37	2.32	$0.73	1.03
Miami, Fla	1919	40,000 (est. winter pop'l'n)	13,950	....	1½	....	....	3.73	....	2.48
San Antonio, Tex.[17]	1919	130,000(est.)	37,500	....	4	98,250.00 (approx.)	0.76	2.62	....	0.66
Trenton, N. J.[18]	1915	103,200	14,428	39,345	1	13,340.34	0.13	0.93	0.34	0.93
" "	1917	113,974	16,029	43,696	1	17,193.13	0.15	1.07	0.39	1.07
" "	1918	116,000	15,097	41,172	1	21,935.09	0.19	1.45	0.53	1.45
" "	1919	119,000	14,860	40,527	1	30,501.64	0.26	2.05	0.75	2.05
Vancouver, B. C.[19]	1910	86,300	35,743	....	2.5	67,311.79	0.78	1.88	....	0.75
" "	1913	118,160	58,315	....	2.5	129,767.14	1.10	2.23	....	0.89
" "	1916	96,993	26,474	....	2.5	62,295.00	0.64	2.35	....	0.94
" "	1919	116,150	22,469	....	2.5	87,491.48	0.75	3.89	....	1.56
Winnipeg, Man	1911	151,718	15,510	....	....	19,371.90	0.13	1.25	....	....
" "	1917	182,848	19,121	....	....	32,601.87	0.18	1.71	....	....
" "	1918	183,595	18,439	....	....	41,242.73	0.22	2.24	....	....

Garbage, Ashes, and Rubbish										
Binghamton, N. Y.......	1918	61,700	17,298	26,591	1.33	$31,393.71	$0.51	$1.82	$1.18	$1.36
" "	1919	64,300	21,440	33,022	1.33	34,800.36	0.54	1.62	1.05	1.22
Chicago, Ill., Wards 8 and 9[20]	1912	....	....	68,581	....	43,833.66	....	....	0.64	....
" " " "	1919	....	....	....	....	....	....	2.50	1.05	....
Clifton & W. New Brighton[21]	1911	....	....	77,290	....	51,670.74	....	....	0.67	....
Louisville, Ky.[22].........	1916	238,910	....	....	....	118,522.00[22]	0.50	....	....	....
Ottawa, Ont............	1918	110,000	40,534	98,670	1	71,800.00	0.65	1.77	0.70	1.77
Paterson, N. J..........	1919	135,000	71,141	142,283	1	86,086.05	0.64	1.21	0.61	1.21
Seattle, Wash...........	1919	315,000	130,000	240,000	1.5	425,183.00	1.35	3.27	1.77	2.18
Toronto, Ont...........	1917	527,556	326,463[23]	584,942[23]	1.5	347,200.00	0.66	1.06	0.59	0.71
" "	1918	535,271	316,793	586,605	1.5	413,026.00	0.77	1.30	0.70	0.87
" "	1919	562,585	330,532	615,654	1.5	452,807.00	0.81	1.37	0.74	0.91
Troy, N. Y.[24]...........	1919	76,500	....	126,000	1.9	71,400.00	0.93	....	0.57	....

[14] Elevation of city, 8 to 500 ft. Miles of street, 155. Collection not done by city but by several private persons. Cost is estimated. Only a partial segregation of mineral waste from kitchen or other waste is insisted on. There are few ashes, as gas is the chief household fuel. Private persons gather the wastes from restaurants and hotels for hog feeding. This is estimated at 1000 tons a year.

[15] Garbage and rubbish not separated, About one-third is hauled to incinerator and remainder to dumps. Ashes negligible in quantity.

[16] Two collections of garbage per week from May 1 to October 15, and one collection of garbage and rubbish together. See note under ashes.

[17] Garbage is hauled by 16 motor-driven trucks with 2 trailers each, and 18 wagons.

[18] This includes combustible rubbish; not incombustible.

[19] All ashes go to a dump; part of the garbage goes to a dump and part to an incinerator. No accurate data as to ashes and garbage dumped.

[20] In Wards 8 and 9 the refuse is mixed and is taken to near-by dumps. The wagons hold 5 cu. yd., and each makes two loads per day. There is one man to each wagon, and he and the team receive $10.50 per day. In summer the mixed refuse is estimated to contain 80% of garbage and to weigh about 1000 lb. per cu. yd. The average for the year is estimated at about 800 lb. per cu. yd. The loads are not weighed. The figures for cost per ton and per yard do not include any overhead and fixed charges.

[21] See *Engineering News*, December 26, 1912. J. T. F.

[22] Includes disposal at dumps, and is exclusive of fixed charges.

[23] The tonnage and yardage of ashes and garbage are given in the statement from Toronto, and, if desired, can be stated, but the costs of each are not separated.

[24] The city is divided into 25 districts. The business section has a daily collection of all kinds of refuse; the residential sections have a bi-weekly collection of garbage and a weekly collection of ashes. All refuse is deposited on an island in the Hudson River, opposite the business section, and the garbage is covered with whatever ashes or refuse is found in the mixed collections.

TABLE 77.—COST OF COLLECTING REFUSE MATERIALS IN AMERICAN CITIES (*Continued*)

City	Year	Population	Total tonnage	Total yardage	Approximate haul, in miles	Total cost	Cost per: Capita	Cost per: Ton	Cost per: Yard	Cost per: Ton-mile
GARBAGE, ASHES, AND RUBBISH (*Continued*)										
Westmount, Que.	1919	19,000	Ashes, 8,196 Garbage and rubbish 11,511 19,707	Ashes, 14,001 Garbage, and rubbish 34,520 48,521	0.75 Very steep grades; maximum 17½%	19,043.87	1.00	0.96	0.39	1.22
ASHES										
Boston, Mass.[25]	1916	762,256[25]	200,117	....	....	$453,387.67	$0.96	$2.27	....	....
Evanston, Ill.	1910	24,978	....	13,461	....	2,174.00	0.09	....	$0.17	....
London, Ont.[26]	1918	50,640	35,420	52,470	0.5	19,270.00	0.38	0.54	0.37	$1.09
Rochester, N. Y.[27]	1917	264,714	191,604	....	....	196,245.41[27]	0.74	1.03	....	....
				1,860[28]	6.25	6,145.20	....	....	3.26	....
Spokane, Wash.[31]	1919	104,000	....	3,100[29]	4.5	4,608.90	....	....	1.63	....
				22,651[30]	2.5	25,595.63	....	....	1.13	....
Trenton, N. J.	1915	103,200	41,573	49,884	0.5	18,360.14	0.18	0.44	0.37	0.88
" "	1918	116,000	48,578	58,290	0.5	29,523.16	0.26	0.61	0.50	1.22
" "	1919	119,000	56,640	67,968	0.625	58,138.60	0.49	1.02	0.86	1.63
Washington, D. C.	1916	353,378	....	135,305	....	68,935.00	0.20	....	0.51	....
" "	1919–20	437,000	97,137	148,300	1.5	110,000.00	0.25	1.13	0.74	0.78
Winnipeg, Man.	1911	151,758	5,227	....	....	5,793.73	0.04	1.11	....	....
" "	1917	182,848	23,487	....	....	15,635.12	0.86	0.67	....	....
" "	1918	183,595	23,444	....	....	19,065.18	1.04	0.81	....	....

Ashes and Rubbish

Baltimore, Md.	1913	574,575	232,360	....	....	$221,115.00[32]	$0.39	$0.95	....	....
Boston, Mass.	1919	491,111	196,683[33]	482,658	0.85	468,329.79	0.95	2.38	$0.97	$2.60
" "	1919	303,705	119,799[34]	293,985	1.00	161,705.58	0.53	1.35	0.55	1.35
Chicago, Ill.	1917	2,547,201	....	1,516,087	....	1,085,781.17	0.43	....	0.72	....
Cincinnati, Ohio	1909	360,000	....	....	....	116,632.00[35]	0.32	....	....	....
" "	1919	401,247	130,531	254,446	1.5	162,299.24	0.40	1.24	0.64	0.83
Cleveland, Ohio	1909	543,000	84,547	202,752	....	119,982.00	0.22	1.42	0.59	....
Columbus, Ohio[37]	1919	238,000	....	200,040 = 39,949 loads	2.5	113,222.78	0.48	....	0.57	....
Detroit, Mich.[38]	1919	993,739	369,846	1,056,704	4.5	1,610,132.64	1.52	4.35	1.52	0.97
Milwaukee, Wis.	1916	440,000	152,800	333,375	....	223,071.81	0.51	1.46	0.67	....
" "	1919	....	....	394,865	....	369,629.45	....	....	0.94	....
Washington, D. C.	1914	353,378	....	....	....	89,590.00	0.25	....	....	....

[25] The population used in the per capita computations is 470,991. The remainder is cared for by private contracts.

[26] One collection of ashes per week from October 15 to May 1. Horse-drawn, 5-cu. yd. wagons and 2½-cu. yd. carts. Horses owned by city, and fed and shod for 56 cents per horse per day. Labor $3.50 per 9-hour day.

[27] The cost of teaming and labor, only, is considered.

[28] Collected by auto from residence district. [29] Collected by auto from business district. [30] Collected by wagons.

[31] General waste collection is not provided in Spokane. Patrons are required to pay directly for any service rendered, and waste collection service is not compulsory; therefore, only about one-thirtieth of the population has regular service, but it is necessary to cover all parts of the city in making collections.

[32] Exclusive of fixed charges.

[33] Collected by city forces within the city limits.

[34] Ashes and rubbish collected and disposed by contract for outlying city districts.

[35] Exclusive of fixed charges.

[36] Average weight of ashes, 52 lb. per cu. ft. Average weight of paper and rubbish, 28 lb. per cu. ft. Approximate average weight of ashes and rubbish, 38 lb. per cu. ft.

[37] Rubbish and ashes collected together, not separated. Rubbish collected twice a month; 22 rubbish routes; 52 teams for rubbish collection. See also reports for 1916, 1917, and 1918.

[38] Garbage is kept entirely separate from ashes and rubbish.

TABLE 77.—COST OF COLLECTING REFUSE MATERIALS IN AMERICAN CITIES (*Continued*)

City	Year	Population	Total tonnage	Total yardage	Approximate haul, in miles	Total cost	Cost per			
							Capita	Ton	Yard	Ton-mile
				RUBBISH						
Boston, Mass.[39]	1919	....	7,546	58,104	0.72	$42,910.62	....	$5.69	$0.74	$7.90
Columbus, Ohio	1918	225,392	....	169,186	....	87,492.37	$0.39	....	0.52	....
Evanston, Ill.	1910	24,978	....	29,479	....	5,108.00	0.22	....	0.17	....
Los Angeles, Cal.[40]	1918–19	543,000	....	46,914	4.5	47,378.72	0.09	....	1.01	....
" " "	1919–20	575,000	....	57,725	4.5	56,738.72	0.10	....	0.98	....
Pittsburgh, Pa.	1917	571,800(est.)	34,342	....	....	....	....	3.00[41]	....	....
" "	1918	577,200(est.)	69,212	....	....	....	....	5.50[41]	....	....
" "	1919	582,600(est.)	75,070	....	....	....	....	6.50[41]	....	....
" "	1920	588,000	....	....	....	....	....	6.50[41]	....	....
Rochester, N. Y.	1917	264,714	8,212	....	....	51,834.07	1.96	6.32	....	....
Spokane, Wash.	1919	104,000	589.3[42]	....	4.5	4,608.90	....	7.82	....	....
			399.5[43]	....	2.5	2,708.61	....	6.78	....	....
Washington, D. C.	1916	353,378	....	157,180	....	28,187.00	0.08	....	0.18	....
" "	1919–20	437,000	17,072	170,716	2.9	65,390.00	0.15	3.83	0.38	1.38
Winnipeg, Man.[44]	1916	182,848	7,187	....	....	15,714.47	0.86	2.18	....	....
" "	1917	183,595	6,510	....	....	16,912.80	0.92	2.60	....	....

[39] Papers, excelsior, etc., collected by city forces within the city limits.

[40] The yardage refers to incombustible rubbish. Combustible rubbish is collected by private persons. Population for 1918–19 estimated, and refers to main city; San Pedro, Wilmington, and San Fernando not included. Motor trucks haul from 6 to 9 miles.

[41] Contract prices.

[42] Collected by auto in business district.

[43] Collected by wagons.

[44] In the reports these figures refer to "tins," probably meaning incombustible rubbish.

APPENDIX TO CHAPTER V

STANDARD FORMS FOR STATISTICS OF MUNICIPAL REFUSE

(The forms herewith reproduced were presented at the annual meeting of the American Public Health Association, Havana, Cuba, December, 1911.)

....................Ending.............19

(1) Name of city....................

(2) Population..........................Year....................

(3) Character of population	Distribution by		
	Property	Area	Population
Per cent residential...........	....	....	....
Per cent business.............	....	....	....
Per cent manufacturing.......	....	....	....
Per cent foreign..............	....	....	....

A. Statistics of Refuse

(4) Average daily quantity of refuse:

	Summer		Winter		Average	
	Yards	Tons	Yards	Tons	Yards	Tons
Garbage........	......	......	......	......	......	......
Ashes...........	......	......	......	......	......	......
Rubbish......	......	......	......	......	......	......
....	......	......	......	......	......	......
....	......	......	......	......	......	......
Total refuse...	......	......	......	......	......	......

(5) Weight per cubic yard:

	Minimum	Maximum	Average
Garbage..................	....	....	....
Ashes....................	....	....	....
Rubbish..................	....	....	....
....	....	....	....
....	....	....	....
Total refuse.............	....	....	....

(6) Quantities of refuse:

	Pounds per capita per year	Pounds per 1000 Population per day
Garbage..................	....	....
Ashes....................	....	....
Rubbish..................	....	....
....	....	....
....	....	....
Total refuse.............	....	....

(7) Mechanical analyses:

	Glass	Bones	Paper	Rags	Metals	Wood	Dust
Garbage......	.....	.....	.....	.....	.....	.....	.....
Ashes........	.....	.....	.....	.....	.....	.....	.....
Rubbish......	.....	.....	.....	.....	.....	.....	.....
....	.....	.....	.....	.....	.....	.....	.....
....	.....	.....	.....	.....	.....	.....	.....
Total refuse.	.....	.....	.....	.....	.....	.....	.....

(8) Chemical analyses:

	Carbon	Water	Ash	Volatile Matter	Grease	Tankage	Ammonia	Potash
Garbage.......	....	....	....	....	....	....	....	....
Ashes..........	....	....	....	....	....	....	....	....
Rubbish........	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....
Total refuse..	....	....	....	....	....	....	....	....

.....

B. Statistics of House Treatment

(9) Size of house can...
(10) Type of house can...
(11) Number of cans...
(12) Location of can...
(13) Is can set out for collector?.............................
(14) Number of separations.....................................
(15) Is the garbage drained or wrapped in paper?...................

C. Statistics of Collection

(16) Is collection done by city or by contract?.......................
(17) Does the city own the stables and equipment?...................
(18) Number of collections per week.................................

	Summer			Winter		
	Business	Residential	Outlying	Business	Residential	Outlying
Garbage........	......	......	......	......	......	......
Ashes..........	......	......	......	......	......	......
....	......	......	......	......	......	.....
....	......	......	......	......	......	......
Total refuse...	......	......	......	......	......	......

(19) Average length of haul: (Grades)
Garbage
Ashes
Rubbish

(20) Type of collection wagons used:

	Garbage	Ashes	Rubbish
Capacity (cu. yds.)	....	....	....
Material	....	....	....
No. of horses	....	....	....
Attendants per wagon	....	....	....
How dumped?	....	....	....
Covered?	....	....	....
Maker	....	....	....
Cost	....	....	....

(21) Frequency of washing wagons:
Method of washing wagons:

(22) Equipment required:

	Summer			Winter		
	Garbage	Ashes	Rubbish	Garbage	Ashes	Rubbish
No. of wagons	......	......	......	......	......	......
No. of men	......	......	......	......	......	......

(23) Cost of collection per ton: Garbage Ashes Rubbish

D. Statistics of Disposal

(24) Method of disposal—Garbage
Ashes
Rubbish

Sanitary Aspects

(25) Disposal by dumping:
Classes of refuse dumped
Number of dumps
Area of available dumping grounds
How are dumps kept up?
Cost of disposal per ton

(26) Disposal by burial:
Location
Character of soil
Area required per ton per year (sq. ft.)
Frequency of using soil
Number of men employed
Cost per ton

(27) Disposal by feeding to pigs:
Is the disposal by the city or by contract?
Annual payment to contractor
Location of piggery
Number of pigs kept—Summer
Winter
Number of pigs lost per year
Are the pigs vaccinated?
Is the garbage sterilized before feeding to pigs?
Number of men employed at the piggery
Gross cost of operation per ton of garbage
Revenue per ton of garbage

(28) Disposal by reduction:
Location of reduction plant
Type of plant
Quantity of garbage reduced per year, tons
Number of men employed at the plant—Summer
Winter
Cost of plant
Gross cost of operation per ton
Quantity and value of by-products
Revenue per ton

(29) Disposal by incineration (including rubbish sorting)
Capacity of each plant............Number of plants.............
Classes of refuse burned
Location of plant
Type of plant
Coal used per ton of material burned
Total number of men employed at the plant—Summer
Winter
Gross cost per ton
Revenue per ton
Cost of plant
Value of power developed
Clinker utilization

E. Miscellaneous Statistics

(30) Under what city department is the work done?

(31) How is manure kept at stables?
How is manure removed?.............. How disposed?.........

(32) Are there loading stations in the city?
If so, how many and for what classes of refuse?

CHAPTER VI

OUTLINE OF METHODS OF FINAL DISPOSAL

The term " refuse disposal " includes the final disposition, utilization, or destruction of the refuse materials after their collection and delivery. Several methods are in common use in different countries, and even in the same country under different conditions. To be satisfactory to a community, the disposal must answer two requirements: It must be sanitary, i.e., it must not cause a nuisance or danger to health; and it must be economical, i.e., the expense must be the lowest that will effect a sanitary final disposal of all the refuse materials.

The demand for a satisfactory final disposal may be progressive, for, it generally becomes more and more important and urgent with the growth of a community. In very small towns, simple methods suffice for a number of years. In large communities, more complex and costly works are necessary. In many cases, also, the relative importance of the collection and disposal is essential. It is obviously unwise to provide costly and comprehensive disposal works before a general and efficient collection service has first been developed and adopted.

There are no marked instances of disease caused or spread by inadequate or improper refuse disposal. The disposal works, however, may, and frequently do, have a secondary effect on public health, produced through flies, mosquitoes, rats, and probably still other causes. These facts may be verified by a visit to any city which has no proper method of refuse collection or disposal, particularly a city in a warm climate; for the modern standard of public health and comfort cannot be maintained without proper attention to them.

One purpose of refuse disposal works is to provide a definite place to which all the waste materials can be brought, and thereby prevent a promiscuous dumping on or near places where it might become objectionable. At such works the materials must be treated so as to control the organic decomposition, to prevent objectionable odors, to recover any valuable parts, perhaps, also, to be used in producing steam, and to reduce the final residue to the smallest quantity and the least offensive condition.

Several methods are available for such disposal, their preference depending on local conditions and the character of the materials. Most of them have been tried and developed to a satisfactory degree of efficiency and economy. They are mentioned below, and the best of them will be described in detail in subsequent chapters.

A:—NATURAL METHODS

1. Dumping into Large Bodies of Water.—Such dumping has been practiced by cities situated near oceans, lakes, or large rivers. The refuse materials are transported on scows to a considerable distance from the shore and there dumped; or, they are discharged into a flowing stream below places of habitation. The method has heretofore seldom been permanently satisfactory, because of the nuisance resulting from floating refuse frequently stranding on the shores.

2. Dumping on Land.—This method is followed more than any other. Dumping garbage, especially in large quantities, without mixing with other materials, however, creates offensive conditions. Putrefaction and fly breeding may soon produce quite serious nuisances. When the garbage is mixed with a sufficient quantity of ashes, rubbish, or street sweepings, the dumping is less objectionable, depending on the quantity and character of such added materials and on the climate. Ashes and rubbish without garbage may sometimes be dumped with no offensive results. A proper mixing of the materials, a covering with a thin layer of excavated soil, and proper control of the dumps, are necessary in order to prevent fly breeding, putrefaction, and fires on the dumps. Such dumps, to be satisfactory, must, nevertheless, be sufficiently far from habitations, and must be given proper attention.

3. Land-fill.—Disposal of refuse by land-fill, with the addition of clean materials, such as earth, is accomplished by filling in large depressions or old excavations. Garbage, ashes, and rubbish, as they are being dumped in the fill, may, for instance, be mixed with street sweepings, or earth taken from near-by building excavations or borrow-pits. When a sufficient quantity of such fairly clean material is mixed with the refuse, unobjectionable oxidation of the organic matter may take the place of putrefaction.

4. Plowing into Soil.—This method is similar in principle to land-fill. It is used in some European cities, in very sandy soils, even for the disposal of mixed refuse. The refuse is first spread over the ground and then within a day or two turned into the soil with a plow.

5. Burial.—A disposal by shallow burial is more applicable to garbage than to other refuse materials, and is generally more avail-

able for small towns than for large cities. Nevertheless, it is used successfully for a very large population in Berlin, Germany, where the soil is almost entirely sand.

6. Feeding to Hogs.—The food value of fresh garbage is sufficiently great to have made feeding to hogs an old and very common method of final disposal. Hotels and eating houses generally have private collections for this purpose, and realize a profit therefrom. In nearly all cities some of the garbage is disposed of in this way. In late years the use of this method has been greatly extended, and it promises further satisfactory development along both sanitary and economical lines.

B.—ARTIFICIAL METHODS

1. Sorting.—Sorting consists of separating, generally by hand, the marketable from the worthless portions of the refuse. It is applicable chiefly to ashes and general rubbish, and in cities where the population is wasteful. The net profit to cities is usually quite small.

2. Incineration.—This method, as its name implies, is the burning of all combustible waste materials in specially designed furnaces. When garbage is collected by itself and alone disposed of by incineration in garbage furnaces, or so-called crematories, an additional fuel, as coal, gas, or oil, must be used. If sufficient fuel is added, such materials may be burned satisfactorily, from a sanitary standpoint. Such burning does not usually result in producing very high temperatures, and therefore such a furnace is spoken of as a "low-temperature" incinerator. Mixed refuse, containing, besides garbage, also sufficient quantities of unburnt coal in ashes and of rubbish or litter may burn readily without additional fuel. Under forced draft, even an intense heat can be created; therefore, such furnaces are called "high-temperature" incinerators. The utilization of the steam and clinker produced by them may yield a substantial revenue and thus reduce the net cost of incineration.

3. Reduction.—The reduction method of disposal is applicable only to garbage and dead animals. The process consists, briefly, in causing the garbage to be separated into four parts: water, grease, tankage, and volatile matter. Tankage is a dry vegetable, animal, and mineral material, which is fairly stable, mostly fibrous, and has some fertilizing value.

The works require the installation and maintenance of apparatus and machinery which is more or less complicated. The method has been economical and satisfactory in some of the large cities of the United States.

4. Miscellaneous.—Under this heading several other processes are mentioned. As yet, none of them has gained an extended field. Only one is described here in detail; it will not again be mentioned.

Grinding (*broyage*) is a method of disposal developed in France. It is more generally applicable to mixed refuse, but is also suitable for garbage, when this is sufficiently dry. The refuse is ground between two rotating steel-toothed plates (patented by Schoeller) from which it falls into cars for removal. The ground material is said to look somewhat like leaf mould, and is used for fertilizing.

Grinding works were established at Vitry, a few miles southeast, and at St. Ouen, a few miles northwest of Paris. Before treatment the larger materials, such as bones, glass, iron, etc., were picked out and sold. The remaining material was then ground and subsequently sifted. About four-fifths of this material were comminuted and sold as a fertilizer, the other fifth was incinerated. The treatment of 10 tons required about 20 h.p. Each of the grinders broke up about 25 tons daily. The odor of the final material, though quite pronounced when it left the works, disappeared in about three weeks.

The average composition of the ground-up refuse, determined by Vivien, Guillen, and others from many samples, was:

Total nitrogen	9.31 parts per 1000
Total phosphoric acid	7.12 parts per 1000
Total potash	5.28 parts per 1000
Total lime	54.90 parts per 1000

The cost of preparing this fertilizer has not permitted a profitable sale, yet it has reduced the previous cost of disposal. It sells for from 1 to 2 francs per ton. The hygienic value of the process is low, as there is no destruction of the pathogenic germs which enter the refuse from houses and streets. Grinding has not yet been tried successfully in America. A recent modification in Europe is a mixing of ground refuse with coal dust to form briquettes which are sold as a household fuel.*

A process for making a poultry food from garbage has been developed by Mr. Edward C. Emery, of Los Angeles, Cal.

Garbage, after some careful preparation, has been fed also to Belgian hares.

Dr. Morgan, of Chicago, has developed a process of reduction by which alcohol is produced from garbage, and Dr. Horst, of the same city, has endeavored to convert the cellulose of garbage into dextrin or dextrose. Neither of these processes has as yet progressed beyond the experimental stage.

* In America the Nu-Fuel Company has recently been formed, having the same object.

CHAPTER VII

DEPOSITING IN WATER AND ON LAND

There are several methods of refuse disposal by which the natural agencies offered by large bodies of water or the soil are utilized. These agencies comprise chiefly the bacteria of the water and soil, the larger forms of vegetable and animal life, and the physical action of rain, frost, sunlight, and other factors.

These methods comprise the earliest in use, and are still frequently practiced by large and small communities. Mr. W. H. Maxwell * (referring to Lucian's "Ancient Rome in the Light of Recent Discoveries") describes a pillar, found among the ruins of ancient Rome, bearing the inscription, "Take your refuse farther on or you will be fined." Even in those early days unrestricted dumping of refuse was apparently considered objectionable.

When depositing methods are properly conducted and restricted, they still offer, for many local conditions, a disposal which is both sanitary and economical. Along the Atlantic and Pacific Coasts, some cities dump garbage and mixed refuse at sea, and several have continued this practice, even after the introduction of modern high-temperature refuse incinerators, whenever sea dumping was found cheaper as well as temporarily unobjectionable.

Two general considerations should here be kept in mind: First, it should be realized that certain characteristics of the various rejected materials hold important relations to the success of each of the above-mentioned methods of disposal. Secondly, these methods themselves should be considered in the light of their "relative values" in municipal sanitation.

Some small communities cannot afford to do more than provide the barest sanitary essentials. They may be obliged to be satisfied with establishing a good collection service, and to dispose of the refuse temporarily and cheaply in the least objectionable manner. Large—and especially wealthy—communities have greater facilities for establishing better but more expensive methods. Local conditions

* "Destruction and Disposal of Town Refuse."

should and will, therefore, control the selection of the more suitable disposal.

A.—DUMPING INTO LARGE BODIES OF WATER

Dumping into large bodies of water has been practiced to a considerable extent in the past, but its use is now becoming more and more restricted. It is a method available chiefly in communities along the seacoast, the Mississippi River, and the Great Lakes. It is available for all kinds of refuse. Due to the fact that the lighter particles of garbage and rubbish drift to and are stranded on the shores, this dumping has sometimes become quite objectionable. Along the Mississippi River, and near ocean bathing resorts, it has in some instances been prohibited because of the undesirable results.

In a report on the garbage disposal for Milwaukee (1907), Hering records that in 1890 the garbage of the city was dumped from large scows into Lake Michigan. This disposal caused a public protest, because particles of the garbage were discovered in the drinking water obtained from the Lake.

The report by Parsons, Hering, and Whinery, on Waste Disposal in New York, makes the following recommendation on dumping at sea:

> "All the refuse collections could be dumped into the Atlantic Ocean, but unfortunately the least harmful material sinks and the foulest floats, so that much of the floatable mass will be scattered along the beaches, through the action of current and wind. This fouling of the beaches creates a nuisance that the public should not be asked to tolerate. The cost of sending the scows so far to sea that there would be no danger of fouling the beaches, and the delays and interruptions caused by storms and ice, forbid the use of this plan. The dumping of refuse at sea should not be resorted to except in cases of emergency, when the period of such sea dumping will be of short duration."

This method of disposal has been used for New York, Boston, Chicago, Cleveland, Milwaukee, St. Louis and New Orleans. Fig. 59 shows a scow being unloaded by hand in the ocean off Sandy Hook. In Europe the cities of Liverpool, Marseilles, and Nice have disposed of their refuse by dumping at sea. The principal requirements are a wharf where the refuse is delivered from the wagons, and proper scows for taking it to sea. The wharf should be of substantial construction, preferably of concrete, with ample facilities for cleaning, and as nearly rat-proof as possible. Fig. 57 (Chapter IV) shows a typical New York wharf. Fig. 60 shows a St. Louis wharf.

The scows should be constructed so that they can be unloaded rapidly and easily kept clean. Deck-scows must be unloaded by

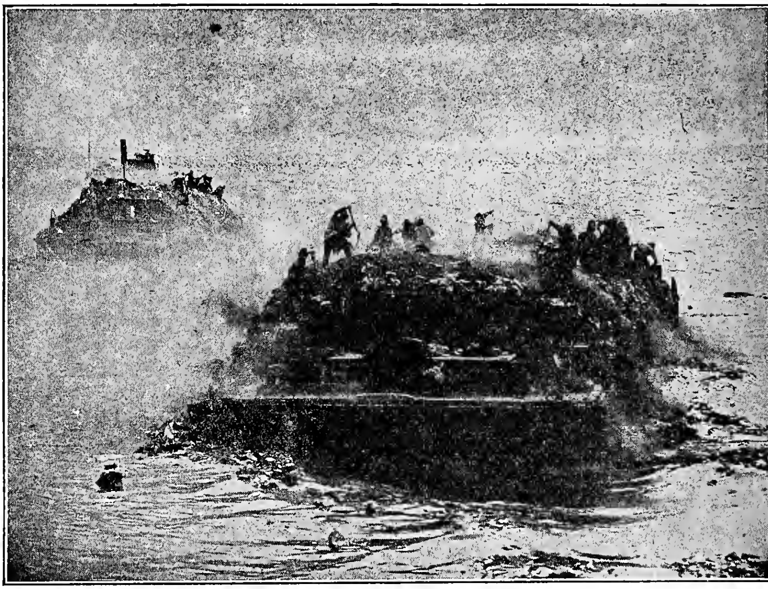


Fig. 59.—Scow being Unloaded by Hand in the Ocean, off Sandy Hook, New York.

(From "The Disposal of Municipal Refuse," by H. de B. Parsons).

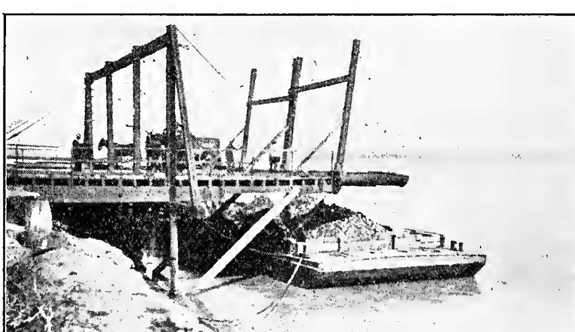


Fig. 60.—St. Louis Wharf for Loading Garbage on Scows.

hand, but bottom-dumping scows, as used by New York City, are preferable. Table 78 shows the cost of dumping mixed refuse at sea in Boston in 1913.

TABLE 78.—COST OF DUMPING AT SEA, BOSTON, MASS.

(From Annual Reports of Board of Public Works, 1911 and 1913)

District No.	Date	Population	Character of refuse	Tons of refuse	Cost	Cost per ton
10	1910–11	80,000	Mixed refuse, principally ashes. No garbage.........	68,606	$21,520.45	$0.3137
10	1912–13	86,254	Mixed refuse, principally ashes. No garbage.........	61,308	25,060.50	0.4088
	Average	......	....	....	....	$0.3612

B.—DUMPING ON LAND

Some kinds of refuse material will probably always be disposed of on " dumps." This method, therefore, should receive careful consideration. Present dumps, in many places, are objectionable, and improvements in their management are desirable. As often practiced, the refuse is taken to waste land or low land and deposited over it promiscuously. The delivery is by wagon, trolley, motor truck, or steam railway cars. Picking over such dumps is often practiced, and sometimes left entirely to scavengers. The presence, particularly, of rubbish, generally having some small value for picking over, increases the desire of some poor people to scavenge the material deposited there.

The kind of materials thus disposed of should control the manner of maintaining such places. Street sweepings in America, building excavations, house rubbish, solid inoffensive manufacturing wastes, and ashes, are generally, at least in part, disposed of in this way. These materials can be handled so that very little, if any, nuisance is caused to near-by property. When rubbish is included, fires are sometimes started, accidentally or intentionally, and may burn for months. The smoke and unconsumed volatile organic matter generally create disagreeable odors. When garbage is present, the nuisance from the smoke and vapors is still more pronounced, and besides, when exposed for several days, it putrefies and may give off

very offensive odors. Flies and rats are attracted by the garbage and breed in it.

Areas available for dumping near the source of the refuse should be carefully considered, because the distance to them affects the cost of collection and the selection of the method of final disposal. If such areas are scarce, they should be reserved only for better materials which may be deposited there without objection, as otherwise an unnecessary addition to the cost of hauling will result. If other methods of disposal are provided for both garbage and rubbish, the available sites will last longer for the better materials, and a much better appearance will be maintained.

The careful consideration of the proper upkeep of dumps is quite important, both for sanitary and economical reasons. If there is a sufficient and regular supply of ashes, street sweepings, and excavated soil, a little additional garbage and rubbish may sometimes be disposed of satisfactorily in this manner; but, in this case, the materials must be adequately mixed and properly spread.

The appearance of such dumps can usually be kept satisfactory by a moderate amount of attention. There should be a sufficient number of laborers to mix the materials, trim the edges of the dump, prevent or extinguish fires, and stop undesirable scavenging. Where possible, the completely filled portions should be covered with soil and seeded. In some exposed locations, it may be advisable to enclose the used portion of the dump with a light, movable, but close, fence. This may hide the unsightly portions, prevent dust and loose paper from blowing away, and more easily prevent undesirable scavenging.

Fig. 61 shows a dump at Louisville, Ky., with the attendant working force, and fairly well-kept premises.

The dumps at St. Louis (Fig. 62) have been well kept. They are used for the disposal of ashes, rubbish, street sweepings, and building excavations. The refuse is brought mostly in wagons which are emptied by tilting, although some of it is brought in private vehicles. The dumps are in ravines and other low-lying areas about the city. On the larger ones, three or four men are employed to trim and keep them in neat condition. These men spread the material and cover the rubbish, or burn some of it in piles. The results are satisfactory, and scavenging is practically abolished.

Probably more refuse is disposed of by dumping than in any other way, and yet it is uncommon to find any special budget appropriation for the proper municipal care of refuse disposal by this method. As a result, there are many well-founded complaints against such places, though this necessary method of refuse disposal will

FIG. 61.—Rubbish Dump, Louisville, Ky.

FIG. 62.—Park Dump, St. Louis, Mo.

remain one of the most economical and—under proper regulations and care—least objectionable ways of disposing of ashes, street sweepings, and some kinds of factory wastes.

The materials that may become offensive should be covered, and scavenging should either be prohibited or put under strict control.

The cost depends largely on the method of discharging the load. Bottom-dump or tip wagons are preferable to those from which the refuse must be unloaded by hand. At Chicago 5-yd. or 6-yd. wagons are used in hauling ashes and rubbish. They open at the back, but do not tip. It takes about twenty-five minutes between stop and start to unload such a wagon. Side-dumping freight cars may be used to advantage when a movable track can be laid along the edge of the dump. A portable hoist may be used to lift removable wagon bodies, and then dump the contents. This has been practiced at Brooklyn, N. Y.

The cost of maintaining dumps ranges from almost nothing up to the cost of burial. Before the War a cost of 10 cents per ton of refuse maintained a large dump in reasonably good condition. The cost of disposal of refuse in this way in different parts of Boston is given in Table 79.

The requirements for the upkeep of dumps may be concisely stated as follows:

a. The dump should be filled so as to limit the length of the dumping edge as much as practicable. The exposed edges are the most objectionable parts because of the difficulty of covering them.

b. A sufficient quantity of ashes, street dirt, building excavation, or borrowed earth should be secured to cover and level the dump properly.

c. Completed portions of the dump should be seeded and partly parked, as is frequently done (New Orleans, Nuremburg).

d. No scavenging should be allowed at the dump at any time, except by city employees.

e. Portable rubbish burners should be kept at the dump to burn large, bulky portions of rubbish not suitable for filling.

f. A water pipe should be laid to each dump to supply water for putting out fires and preventing dust.

g. A sufficient supply of kerosene, cresol solution, or other fly germicide should be kept on hand, so that fly maggots may be killed before developing into flies. In addition, fly traps should be kept at the dumps, as done in Worcester, Mass. (Fig. 63).

h. Only such garbage as cannot be readily kept separated from other refuse should be allowed to be dumped.

i. The used portion of each dump should be enclosed with a light

TABLE 79.—COST OF DISPOSAL BY DUMPING ON LAND, IN BOSTON, MASS

(Data from Annual Reports of Board of Public Works)

District No.	Approximate population served	Character of refuse	Data for 1910–11			Data for 1911–12		
			Tons of refuse	Total cost	Cost per ton	Tons of refuse	Total cost	Cost per ton
1	75 000	Mixed refuse, principally ashes. No garbage	14,540	$1240.56	$0.051	24.824	$1651.86	$0.066
3	42,000	do.	16,577	3060.67	0.184	15,386	4031.74	0.262
5 (part) and 7	145,000	do.	54,169	8054.18	0.149	60,670	9054.42	0.149
5 (part) and 7	145,000	Store refuse, principally papers	718	187.32	0.261	180	33.60	0.187

movable board fence, to facilitate control and prevent paper and dust from blowing away.

j. The dump should be in charge of a uniformed foreman with authority to enforce the regulations.

The report of the Department of Public Works of Milwaukee for 1911 states that 173,327 cu. yd. of ashes and rubbish were hauled to dumps. The cost of the dump maintenance was $2,033.97 for labor and $40.00 for water. The resulting cost, therefore, was $0.012 per cubic yard.

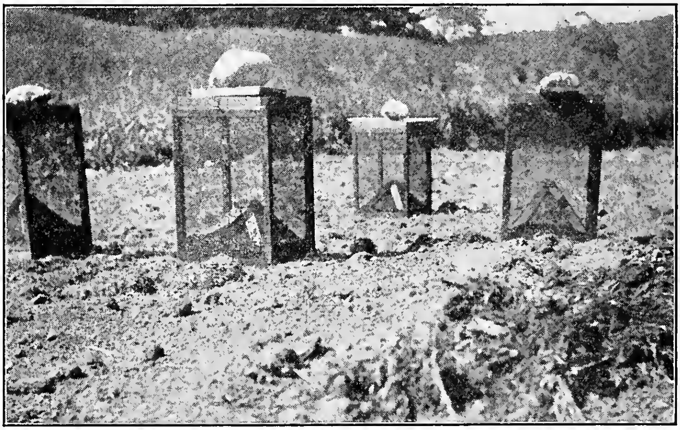


Fig. 63.—Fly Traps over Buried Fish Scrap, Worcester Hog Farm.

A few data in reference to the cost of dumping on land at Milwaukee and Chicago are shown in Table 80.

In Detroit, large excavations in brick yards have been filled in with rubbish, thus accomplishing two desirable purposes.

Paris disposes of much of its organic refuse on land, where it is spreàd out for fertilizing purposes; it is delivered by train or boat to the outlying country.

Table 81 shows the cost of upkeep of dumps in several American cities.

C.—LAND-FILL

This method of disposal is a development of dumping, but differs from it, because it includes a definite process of mixing the organic with a sufficient quantity of inorganic materials to make them odorless. Generally, a sufficient quantity of earth is mixed with the refuse to

insure a thorough digestion of a moderate quantity of garbage and other putrescible materials. Such earth may be taken either from building excavations or from borrow-pits. Street sweepings, unless largely rubbish and street manure, may also answer the same purpose.

TABLE 80.—COST OF DUMPING ON LAND

(Data from Reports of Board of Public Works)

Year	Milwaukee, Wis.			Chicago, Ill.		
	Cubic yards of ashes and rubbish hauled to dumps	Cost of dump maintenance		Cubic yards of ashes and rubbish hauled to dumps	Cost of dump maintenance	
		Per year	Per cubic yard		Per year	Per cubic yard
1911	173,327	$2,073.97	$0.012	....	....	....
1912	293,646	....	....	....	....	....
1913	319 848	....	....	1,514,233	$68 732.05	$0.045
1914	321,669	10 557.00	0.033	1,460,616	75,655.95	0.052
1915	320 373	7,357.25	0.023	1,487 431	72,928.72	0.049
1916	333,375	6,162.85	0.018	1,499,667	73 922.89	0.049
1917	....	....	....	1,516,087	64,283.79	0.042
1918	....	....	....	1,371,490	61,828.34	0.045

TABLE 81.—COST OF UPKEEP OF DUMPS IN SEVERAL AMERICAN CITIES

City	Year	Total population	Cost			Notes
			Total per year	Per capita	Per ton	
Rochester, N. Y.[2]	1914	245,077	$12,858	$0.052	$0.074	
Toronto, Ont.[4]	1916	....	5,300	....	0.049	One dump
Savannah, Ga.[4]	.....	....	....	....	0.67	
St. Paul, Minn.[4]	1916	247,232	4,002	0.017	....	
Richmond Borough, N. Y.	1911	90,000[1]	5,315[2]	0.120	....	Two districts
Boston, Mass.[3]	1912	262,000	14,738	0.056	0.159	Three districts
Louisville, Ky.[4]	1916	238,910	4,240	0.018	$0.042	
Paterson, N. J.[5]	1920	145,000	$9,622	$0.066	....	

[1] Assuming half the population to be tributary.
[2] Report of Bureau of Municipal Research.
[3] Annual Reports.
[4] Data for Toronto, Savannah, St. Paul, and Louisville obtained by letter.
[5] 123,381 cu. yd. taken to dumps.

Such a method of garbage disposal has been used at Davenport for a number of years. The city is reclaiming, in this manner, an area along the Mississippi River, by dumping over the edge of the river bank, which, at ordinary stages, is from 8 to 12 ft. high. The wagons are backed to the edge and emptied by tilting. Piles of material for mixing and covering are always kept in readiness along the top of the bank, and are spaced so that there is just enough room between the piles for the wagons to back up to the edge. After the wagon pulls out empty, two men, with long-handled shovels, spread the covering material from the two adjacent piles. In a very few minutes, therefore, the garbage is covered to a depth of from 6 to 10 in. This depth has been found sufficient for satisfactory protection.

At times of high water in the river, it is necessary to protect the edge of the fill by placing "mattresses" over the bank. These are made of ordinary chicken wire, and are 6 ft. wide and 15 ft. long. Two strips of wire, about 10 in. apart, with old hay held between, are laced together with marline. The mattresses are hung over the face of the bank and weighted with rip-rap. The wash of the banks and the silt of the river very quickly seal the mats and prevent them from being washed away.

During the summer, about 1200 cu. yd. per month (20 tons per day), of garbage and night-soil, are disposed of in this way at Davenport. They are mixed with material from cellar excavations, ashes, street sweepings, and spoil from paving and sewer work.

At times it has been necessary to purchase additional material for mixing. Under these conditions, about 2 cu. yd. of covering and mixing material have been required for each 1.5 cu. yd. of garbage or night-soil. In 1916 a concrete retaining wall was built in order to protect the dump from the river wash.

It is stated that the land made by this fill is very valuable. The filling is controlled by a foreman and three laborers. The cost of this force ranges from 18.2 to 35.0 cents per cubic yard, the average being 28.0 cents. This represents the entire cost of the garbage disposal, and, in 1916, was equivalent to about 14 cents per ton.

At New Orleans this method has been followed for the disposal of all kinds of refuse except garbage. Small parks have been constructed on the filled land.

A similar method of disposal is used at Essen, Germany, where there are a number of low areas which can take a fill of from 20 to 30 ft. General house refuse is dumped there and mixed with earth. In warm weather, some lime is added; this tends to prevent the breeding of flies and also the putrefaction of the garbage. These fills are kept in good order by laborers, and some scavenging is permitted.

The City of Nuremburg, Bavaria, also disposes of its refuse by this method. Many acres of parks have been made on areas which were formerly sand pits excavated for building purposes. The city officials have demonstrated that this method is sanitary and does not cause any nuisance, when properly conducted; it is also economical, if the increased value of the reclaimed land is considered.

An approximation to such a disposal is sometimes found by limiting the quantity of garbage taken to the fill, or, better, keeping it out altogether. It rarely happens, however, that all the garbage can be kept out, and often too little attention is given to securing a sufficiently safe mixture. Frequently, also, the proportion of rubbish is too great, and fires have been lighted to reduce its quantity, thereby causing disagreeable odors.

The essentials for a successful practice of this method of land filling are a sufficient quantity of earth, and a proper mixing and trimming. The earth furnishes the aerobic bacteria to oxidize the organic matter, and adds stability to the fill. As a precaution, it is well to have on hand at such dumps a sufficient quantity of liquid germicide, such as cresol solution, pine oil disinfectant, or a solution of gas-house waste and kerosene, for use in killing fly maggots.

In Chicago, in 1913, owing to some difficulties with the garbage reduction contractor, it became necessary to provide a temporary means of disposing of the garbage. It was treated with an acid and then dumped and spread out in alternate layers with ashes and rubbish. The garbage was brought to the wharf in scows. In cold weather it quite commonly froze in the wagon bodies.

The plant consisted of a wharf, 150 ft. long, five wooden vats for treating the garbage, a track along the wharf, two 5-ton locomotive cranes, 1200 ft. of movable track for use with side-dumping cars, a heating plant, and a storehouse. Each vat had a capacity of 50 tons of garbage, and was covered and well under-drained.

The garbage was dumped into a vat, until within 2 ft. of the top. The vat was then filled with water mixed with a sufficient quantity of crude hydrochloric and sulphuric acid, in equal parts, to make a 1% solution. The charge was allowed to stand in the vat over night, and the liquor was then drawn off through the under-drains. When the garbage was fairly dry, the treated material was picked up by the cranes, deposited in side-dump cars, and drawn by horses to the dump. The garbage was carried in wheelbarrows and spread over the bottom of the excavation to a depth of about 1 ft. At the same time the city ash wagons delivered their material along the edge of the dump. At night the ashes were distributed over the garbage to a depth of from 18 to 24 in.

This process was continued from October 1, 1913, to June 15, 1914, or for about 200 working days, the average quantity of garbage handled per day being 300 tons. The settlement amounted to about 9 ft. from an original depth of from 25 to 35 ft. After one year, some of the material was excavated to a depth of 5 ft., and was found to be dry and inoffensive. The process was devised by Dr. G. B. Young, the Health Commissioner of Chicago, from whose report the foregoing account is taken.

D.—PLOWING INTO THE SOIL

The disposal of refuse materials by plowing into the soil is a method very similar to burial. The refuse materials are spread over the ground in a thin layer, and are plowed in at intervals, by which process they are partly mixed and partly covered. This method has been used at Cologne, Germany, where mixed house refuse is spread over fields having an area of 50 acres or more, and at intervals of one month is plowed into the soil.

For raw garbage this method is not as suitable as burial, because in warm weather it must be covered very quickly in order to prevent a stench.

The plowing method for garbage disposal was tried at York, Pa., in 1906, but too long an interval was allowed between the plowings, and the objectionable odors which resulted were observable for several thousand feet.

With European mixed refuse, the offense from putrid garbage is largely eliminated. A greater trouble results from many loose pieces of paper blowing about, which was especially noticeable on the Cologne fields. This method does not have a wide application.

At the Worcester hog farm, some garbage has been disposed of alternately by burial and by plowing into the soil (Fig. 64). The soil is a sandy glacial drift, well suited for the burial process. Plowing in thin layers was found to cause less trouble from flies than dumping and covering in pits. It was found necessary to have laborers trim the furrows in order to cover the garbage thoroughly.

E.—BURIAL

When properly done, a shallow burial in the soil constitutes a fully sanitary and adequate method of disposal, and particularly for garbage, to which it is generally confined. Manure and night-soil can also be well disposed of in this way. In small communities it is generally best to cover both of these materials with 6 in. of soil.

There is very little advantage in burying ashes, street sweepings, and the like. Rubbish is generally too bulky for burial, and its perishable parts are not decomposed so easily or so quickly as to produce any putrescence.

The success of this method depends on an aerobic bacterial decomposition in the soil. Therefore, garbage must not be buried so deep that the air cannot reach it freely; and the layer of garbage must not be deeper than that which the soil bacteria can penetrate and where they can still digest it. When these two precautions are observed, burial is simple and quite satisfactory.

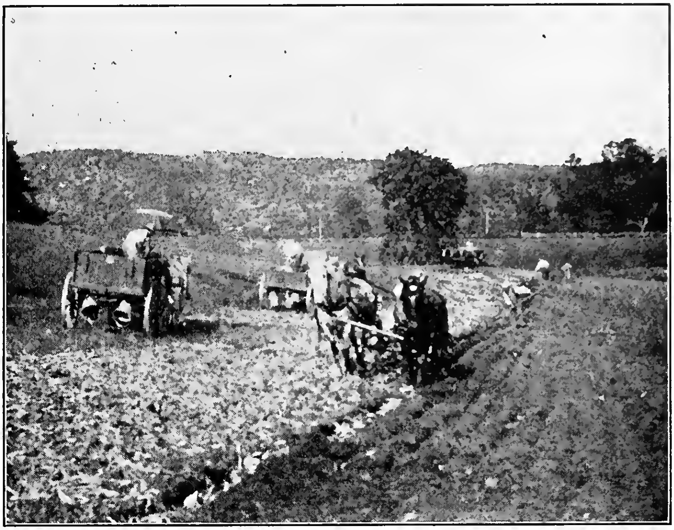


Fig. 64.—Plowing in Some Garbage, Worcester Hog Farm.

The time required for the complete decomposition of the garbage depends on the nature of the soil. When it is sandy and open, and in temperate climates, garbage can be decomposed thoroughly at the end of two years. If the soil is heavy, like clay, and the winters are severe, it will require about four years. At the end of these periods, the soil can be reused for assimilating further doses. To get good results from this method, it is essential to have adequate drainage. The site must not be flooded, and the ground-water must not rise to within 12 or 18 in. of the surface. If the garbage is deposited below the ground-water level, a much slower bacterial decomposition takes place.

The treatment of the burial field is simple. A trench is dug, about 3 ft. wide and 10 or 12 in. deep. The garbage is dumped into it from the wagon and spread out in a layer from 6 to 8 in. deep. When an adjoining trench is dug for the next day, the excavated material is used to cover the garbage, already spread, to a depth of from 4 to 6 in.

In cold winter weather, the garbage sometimes may be spread on the ground and covered with ashes, which are plentiful during that season. The mixture is then plowed into the soil in the spring. A sufficient length of trench can be plowed open to last through the winter. For an average winter, lasting four months, it would be necessary to open 1500 ft. of trench to provide for one ton daily. The garbage in the trenches may be covered in the winter with lumps of frozen earth picked from the earlier excavations and piled up in ridges adjoining the trench. Very little decomposition takes place in winter, and the covering can be trimmed and reinforced in early spring. There need be no fear of flies, either feeding or breeding at the burial field, if the garbage is covered, and the grounds are kept clean and well trimmed. If small breeding centers for flies, rats, and mice develop, they can be stamped out with a suitable germicide.

The equipment should include a tool-house, with a room for the keeper, and a stove. There should be a place for washing the wagons, and preferably, also, a wagon scale. Building a fence or planting a hedge around the field would serve to screen the operations, if this is desirable.

In large cities sufficient area for burial is not generally available within reasonable hauling distance. In Milwaukee this method of garbage disposal was practiced during the winter, until a few years ago. At that time two disposal areas were available. One had a sandy soil, the other was clayey. The trenches were from 3 to 4 ft. wide and about 12 in. deep. The depth of the garbage placed in them was about 8 in. in summer and about 14 in. in winter; it was then covered with the excavated material from the next adjoining trench. A section of trench from 10 to 15 ft. long sufficed for about one ton of garbage. In the sandy location, the soil could be reused after one year, but, in the clay location, only after four years. The assimilation of the garbage was assisted by plowing every six months.

The garbage did not act as a very good fertilizer. The first summer after the clay ground was treated, small vegetables could be raised. The soil at this time was not good for growing grain; but, with frequent deep plowing, grain could be grown during the second summer. At Milwaukee, the annual reports of the Commissioner of Health for 1907 give the cost of burying garbage in winter at from 50 to 60 cents per ton.

Disposal of garbage by burial is commented on in the special report (1910) of the Ohio State Board of Health on the collection and disposal of city wastes in Ohio as follows:

"This method of disposal may be considered as the primitive one in this State, as has been the case elsewhere. It was found to be in use in but one of the cities studied, namely, Columbus, but in a great number of municipalities throughout the State it is the customary method of disposal. This is especially true of the smaller communities. At Columbus, this method was employed as a temporary expedient during the time elapsing between the expiration of a contract with a private company and the construction of a municipal reduction plant.

"To provide a place for the disposal of garbage, the City of Columbus purchased a farm of 70 acres suitably located southwest of the city, and employed it continuously from 1906 to 1910 as a burial ground for all garbage, night-soil, and dead animals from the city. The material was placed in pits dug to a depth of about 2 ft., with an average width of 7 ft., and of indefinite length, and covered with a layer of from 1 to 2 ft. of loose soil. Approximately 15 acres of land were used in this way each year.

"Disposal by burying, when properly conducted and when the point of disposal is suitably located, gives no cause for objections from a sanitary viewpoint. At Columbus the method was entirely without objection, as the burial ground was at a distance of at least 1000 ft. from any dwelling, and extreme care was taken to avoid the production of odors by prompt covering of the material after dumping. The principal objection that has been raised to this method of disposal, especially in large cities, such as Columbus, has been the extremely long haul which is required in conveying the garbage to the burial ground. In small communities where this is not objectionable, the method of disposal is entirely satisfactory.

"After burying, the garbage slowly undergoes decomposition, and finally occupies a layer one-fifth to one-third of its original thickness. In the spring of 1909, several holes were dug to uncover garbage, which had been buried for different periods, with a view to discovering to what extent decomposition had been completed. The following was the result of the observations.

" *Time buried*	*Condition.*
6 to 9 months......	In very high state of putrefaction. Objectionable odor. Constituents readily distinguishable.
17 months.........	In a somewhat less state of putrefaction; still readily distinguishable.
20 months.........	Still decomposing and of some foul odor. Character more or less distinguishable.
30 months........	Material innocuous, resembling humus matter, and having a slight musty odor, very faintly distinguishable.

"It will be seen from these observations that the garbage was not rendered entirely stable until two and one-half years after its burial, but, at this

time it was found to be in such condition that the land was again ready to be used for burial."

The mixed refuse of several million people is disposed of by burial at Berlin, Germany, on a large scale. The soil is almost entirely sand, and is converted into very productive land. So long as sufficient land is available at an economic distance, no other method of disposal will be used.

At Champaign, Ill. (1916), garbage has been disposed of successfully by burial for the last twelve years. A burial field of 3 acres (Fig. 65), about a mile out of the city, is rented for $100 a year. One

Fig. 65.—Burying Garbage, Champaign, Ill.

man cares for this field, to which are brought about four loads of garbage per day. It is buried in trenches about 4 ft. deep. An excavation made in the garbage buried twelve years ago, showed it to be still decomposing and to have a foul odor, indicating burial at too great a depth. In Rome, garbage buried about 1000 years ago, at a depth of from 25 to 30 ft., when examined, near the end of the 19th Century, had not completely decomposed.

An estimate of the cost of garbage burial for a small community of 5000 people, producing, in 1912, 4 tons of garbage per day, is as follows: *

* From the Report on the Collection and Disposal of Refuse in Winnetka and Glencoe, Ill., by Greeley. 1912.

First Cost.	
Land, 10 acres at \$500	\$5000
Attendant's house	500
Washing platforms	200
Water connections	600
Drainage	300
Tools and hose	100
Planting	400
Roadway	400
	\$7500
Contingencies	500
Total	\$8000
Annual Cost.	
Labor	\$1200
Supplies	200
Repairs	100
Spring plowing	50
	\$1550
Interest on \$8000 at $4\frac{1}{2}$%	360
Total	\$1910
Average cost per ton of garbage	\$1.60

In his report on garbage disposal at Davenport, Mr. John W. Alvord states that the cost of covering about 22.5 tons of garbage per day was about 37.5 cents per ton. The covering was soil, chiefly sand and some clay. It was very satisfactory.

F.—SUMMARY AND CONCLUSIONS

The natural methods of refuse disposal described herein need, in our opinion, more consideration than they have received in the past. Their simplicity and economy heretofore have tended toward neglecting a sufficient study of their efficiency and cost; yet they constitute an important branch of city refuse disposal work, and, as some of them have an extensive application, they need greater study. More attention should be given, particularly to the dumps, so that they may be kept inoffensive and clean, which is seldom the custom at present.

Shallow burial of garbage is the best natural treatment, and should be considered carefully when artificial methods cannot readily be made sanitary or economical.

Depositing refuse in large bodies of water should be generally considered only as a temporary expedient, or be used in an emergency, unless the floating matter can be prevented from reaching the shores and it is the least expensive method of final disposal.

CHAPTER VIII

FEEDING GARBAGE TO HOGS

Garbage can be finally disposed of by feeding it to hogs. It is given to them raw or is first cooked or warmed, and sometimes it is enriched with a stock food. Feeding is practiced to a large extent in the United States. At farms and isolated country houses it has been an old and common custom to use garbage for feeding hogs and chickens, and farmers have found it profitable to collect it from near-by towns. In small communities this method persists, and even in New York, Philadelphia, Boston, Chicago, St. Louis, and other large cities, hotel garbage is disposed of extensively in this way.

Providence, Fall River, Pawtucket, Worcester, and many other cities in New England, feed all their garbage to hogs. In 1904, an investigation in Massachusetts, by the State Board of Health, revealed the fact that 61 cities and towns in that State were disposing of garbage in this way. In the Middle West this method is used at Grand Rapids, St. Paul, Omaha, Denver, and elsewhere. Not until 1914 was it abandoned in Los Angeles in favor of reduction.

Table 82 contains approximate data from a number of cities in various parts of the United States.

During 1917, owing to war conditions, feeding of garbage received much special attention. The United States Food Administration commended its use as a food-producing and waste-conservation measure, and the War Department adopted it at many of the Army Camps and Cantonments. Under this stimulus, much careful study has been directed to it, and much useful information has been gained.

Present practice (1919) may be grouped in several classes, somewhat as follows:

(*a*) The garbage is collected by the city, and is delivered at transfer stations, in or near the city, to contractors who maintain and operate hog farms. This is done at Grand Rapids and elsewhere.

(*b*) The garbage is both collected and disposed of by contractors, as at Denver, Topeka, Omaha, Kansas City, and elsewhere.

TABLE 82.—APPROXIMATE DATA RELATING TO HOG FARMS AND THE DISPOSAL OF GARBAGE BY FEEDING TO HOGS

(Data from Report by S. A. Greeley on Garbage Collection and Disposal for Toledo, Ohio, in July, 1920)

City	Average tons of garbage per day, 1920	Where delivered	How delivered	Distance city to farm, in miles	Area of farm, in acres	Number of Hogs			Number of men employed	Hog manure, in per centage of garbage	Area of pen, in square feet per hog	Area of feeding platforms, in square feet per hog	Payment to city per ton at place of delivery
						Capacity of farm	Actual number in 1920	Per ton of garbage					
Baltimore......	33	Farm	Boat	12	157	5,000	850	26	8 to 14	40	7.6	4.8	$0.52
St. Louis.......	......	Farm	......	15	......	......	......	......	......	......	......	......	0.25
Buffalo.........	60	Farm	Tractors	4	69	5,000	4300	71	12	30	7.5	17.0	0.50 to 0.90
Newark........	38	Farm	Team	0	8	4,000	1210	32	5	50	7.5	2.4	1.20
Minneapolis....	......	Tr. station	Railroad	6	80	2,500	2500	50	......	......	......	......	1.26
Portland, Ore...	......	Tr. station	Team	1	......	......	......	......	......	......	......	......	3.90
Denver.........	60	Houses	Team	0.5	......	10,000	......	......	......	......	......	......	....
St. Paul........	......	....	......	......	......	......	......	......	......	......	......	......	1.95
Louisville......	......	Tr. station	Team	......	......	......	......	......	......	......	......	......	3.50
Akron..........	47	Farm	Team-trucks	......	200	......	......	......	......	......	......	......	1.00
Providence.....	100	Houses	......	7	1000	......	......	......	......	......	......	......	....
Worcester......	30	Houses	Team	0	376	3,000	3000	100	10	65	7.2	......	....
Grand Rapids...	36	Tr. station	Railroad	43	240	6,000	......	......	......	......	......	......	0.25*
Omaha.........	50	Farm	Team	0	......	5,000	......	......	......	......	......	......	0.06
Salt Lake City..	15	Tr. station	Railroad	6	60	2,000	......	......	......	......	......	......	....
Utica..........	25	Farm	Tractors	4	160	1,600	......	......	......	......	......	......	....
Topeka.........	10	Houses	Team-trucks	1	15	800	......	......	......	......	......	......	0.00
Madison.......	10	Farm	Team-trucks	3	......	......	......	......	......	......	......	......	....
Highland Park..	15	Tr. station	Team	4	40	750	750	53	......	50 to 57	3.0	3.0	0.45

* Contractor pays an additional $0.20 per ton for freight to his farm.

(*c*) The garbage is collected and disposed of by the municipality. Frequently the hog farm is at the city or county poor farm, as at Worcester, and other New England cities.

(*d*) The garbage is received by a comparatively large number of farmers for feeding hogs on their farms. The collections are generally made by the farmers themselves, but in some cases the city cleansing department delivers it to them. In Evanston, Ill., and other smaller cities, the garbage is collected by the city and hauled to a central point, where farmers who want it may take it away. Whatever is left is burned in an incinerator or buried.

A. FUNDAMENTAL CONSIDERATIONS

1. Fresh and Clean Garbage.—The chief requirements in feeding garbage to hogs are, to keep it as fresh as possible, so as to preserve the highest food value, and to safeguard and maintain the health of the hogs. Both of these requirements call for special sanitary care in the house treatment, collection service, transportation system, and the farm. As the highest food value depends on cleanliness and freshness, so do these in turn depend on the source of the garbage, the care taken in the separation, the frequency of collection, etc. Selected hotel garbage may have a food value ten times as great as that of mixed city garbage.

For feeding purposes the garbage should not contain any noticeable portions of ashes, rubbish, glass, or other foreign matter. Tin cans are objectionable because they cut the mouths of the hogs. They should be removed preferably before the garbage is placed in the feeding troughs.

In warm seasons, particularly, the garbage should be delivered to the hog farm promptly. Some managers of such farms consider twice a week, except in hot weather, a sufficient frequency of collection. This is the practice in Worcester, both in winter and summer. However, a more frequent collection is preferable, and it is desirable that the garbage be fed to the hogs in summer within fifty or sixty hours after it is produced, depending on the temperature.

In large cities collection and delivery routes are long, and, further, it is difficult to exclude all foreign material, except at hotels and eating houses. Therefore, feeding with domestic garbage from all buildings in large cities is apt to be less sanitary and less profitable, and the practice, therefore, is quite limited.

In some instances garbage is sterilized by cooking before it is given to the hogs. When this is done, some grease can be recovered by skimming it from the top of the containers. In the Secaucus

district of New Jersey, where several thousand hogs are fed on garbage, chiefly from hotels and restaurants, practically all of it is cooked for from six to nine hours in large open vats. We are informed that this cooking appears to have had no bad effect on the hogs. The grease recovered is said to be equal to from 3 to 4% of the raw garbage. Experience with cooked city garbage at Denver and Grand Rapids, however, was not favorable. It is probable that certain organic acids were formed, and these seem to have irritated the stomachs of the hogs. Furthermore, these animals cannot well reject undesirable particles from the cooked garbage. On this account, and because of its cost, cooking has not everywhere been practiced where garbage is fed. Sometimes in winter it is simply warmed and softened by a short cooking, especially for young stock. At Worcester it is soaked in warm water.

2. Diseases of Hogs.—Hogs are subject to cholera, pneumonia, foot-and-mouth disease, and other ailments. The chances of death, however, can be greatly reduced by proper care.

a. Cholera.—Hog cholera can be largely controlled by suitable vaccination. It is regarded as a germ disease, and contagious, although its specific organism has not yet been isolated. Its first appearance in the United States was in 1833. The first noticeable symptom is loss of appetite, generally preceded by some rise in blood temperature. A cough usually accompanies the disease. Constipation often occurs in the early stages, and the stools are covered with mucus. In later stages diarrhœa appears; the eyes become festered, and red blotches appear on the skin, especially in the abdominal region. The hog is reluctant to leave its bed, and frequently burrows under the bedding. Death may occur within twenty-four hours, or the disease may run for about six weeks before recovery. A pink color of the skin is typical of a death from cholera.

Some details concerning the medicines to combat hog cholera are given in the following abstracts from a letter to the authors by Professor Frederic Bonnet, Jr., formerly of the Polytechnic Institute of Worcester, Mass., and in charge of the hog farm at Worcester.

The " virus " is essentially the blood of a hog actively suffering from hog cholera. It contains the active principle (micro-organisms and their metabolic products) of the disease. Collecting this blood must, of course, be done in such a way as to protect it against contamination—by taking the usual bacteriological precautions. It is usual to add, as a preservative, a fractional percentage of phenol, tricresol, etc. These preservatives, in the concentration used, have practically no effect on the virus itself. When a small portion of such blood—or " virus "—is inoculated into a healthy unimmunized hog,

the animal, in the course of a few days, shows all the evidences of the disease; but, with such small inoculations, the animal organism has an opportunity to develop sufficient antitoxin to neutralize the virus or poison. Once stimulated by the virus to produce antitoxin, the organism apparently continues to produce it, which gives it immunity for the remainder of its life.

The " serum " is prepared from the blood of a hog which has had the cholera and has completely recovered. In other words, a hog having in its blood sufficient antitoxin to give it immunity. As in the case of " virus," blood is drawn, under proper conditions, and is allowed either to coagulate or is citrated, i.e., treated with sodium citrate to prevent coagulation. Larger yields are obtained by the latter method. A small quantity of the preservatives—mentioned previously—are added to the serum, as was the case with the virus.

Treating a hog with serum alone will give it only temporary immunity, and the immunizing effect of the serum very soon disappears, because serum alone does not stimulate the organism to produce antitoxin itself. It is important, therefore, that a hog should have had the disease in order that it may be immune.

In the case of hogs fed with municipal garbage, one very important fact is often lost sight of, namely, that any municipal garbage may be infected. This is due, largely, to the fact that hogs are killed in the initial stages of the disease, and the trimmings get into the garbage. Hence, too much stress cannot be laid on the importance of proper inoculation; and by this is meant, not only the technique of actually doing the work—which is simple enough—but the use of " standardized " serum and virus.

Some hog farmers, and even some State agricultural colleges, have attempted to use "natural virus," i.e., that taken from a hog presumably sick with cholera. In such cases there was no assurance that the hog was not really on the high road to recovery, and its blood contained very little, if any, virus. In consequence, the virus was really absent, or so dilute as to be inactive, and erroneous conclusions were drawn.

The virus, after being prepared, should be carefully tested on healthy animals, and the course of the disease followed closely. The same is true of the serum. Unless this is done, there will certainly be a false sense of security in the remedy.

In Massachusetts no virus or serum is allowed to be used until it is approved by the State Bureau of Animal Industry, which maintains a farm for this very purpose. The serum and virus should retain their potency for a given period. It is understood that the

larger manufacturers of these remedies are undertaking to supply material of this character.

The most serious drawback, in recommending garbage disposal by feeding, has been the difficulty of obtaining reliably tested and standardized virus and serum in all States. The success of the feeding method in Massachusetts has been due, largely, to the excellent work of its Bureau of Animal Industry, the head of which is Dr. Edward Cahill.

The virus of hog cholera and the serum may be injected simultaneously, the virus at one point and the serum at another. This treatment produces lasting immunity. For a short time, just before and after vaccination, the hogs should receive special food and care.

At the Grand Rapids farm the hogs are vaccinated when about six weeks old. Mr. Alva Brown, the manager, describes the vaccination as follows:

"The pigs are treated at the age of from four to ten weeks and while nursing; a pig is held in position by one man and, by hypodermic, virus is injected in the inside of the left ham, which furnishes the disease germ; serum is injected into the right ham, which furnishes the combative qualities in the pig's system; this is known as 'the simultaneous treatment' and is not always practical because of the danger in handling the virus on the part of the operator. My losses in pigs from this treatment in the summer months will not average above 5%, but in the other months, which are not so favorable to the pigs, the losses are considerably greater, and the percentage depends on the weather conditions. I treat pigs at this age because of the lesser amount of material required, as this is regulated by the avoirdupois of the animal. Another reason is that all our stock must be immune, otherwise the animals are quite sure to contract the disease early in life. If any animals are to die through vaccination or through disease, we want it to happen while they are young, and before any investment of consequence in their development has been occasioned. My experience indicates that treatment by this process makes the animal immune during its natural life, which does not often exceed four or five years and is generally much less. My pigs being from immune sire and dam makes them less susceptible to the disease if not vaccinated, and less liable to death through the vaccinating process. It has been estimated that pigs from stock where immunity extends back several years on both sides have about 40% of immunity, even though no treatment is given, and I believe this is a fair estimate."

Inoculation against cholera at the Worcester hog farm is described by Professor Bonnet, as follows:

'The entire stock is treated by the so-called double treatment method (virus and serum). Pigs five to six weeks old are inoculated with serum only. This treatment carries them for about seven weeks, when, at the weight of about 40 to 50 lb., they are given the double treatment, virus and serum. State Veterinarians under the State Bureau of Animal Industry do this work

free of charge, the department merely paying for the serum and virus used and for the necessary help. The cost of treatment depends upon the size of the animal, since more serum is used the larger it is.

"The serum costs $1\frac{3}{4}$ cents per c.c., and about 20 c.c. are used for a 40- to 50-lb. hog, live weight, so that the total cost of treatment, exclusive of help, is therefore about 70 cents per pig. The place for injection (between the hind legs) is scrubbed with soap and water containing lysol or similar disinfectant, and swabbed with tincture of iodine after puncture. Not one hog in 500 is lost, and there is no trouble from ulcer formation if the inoculation is properly done. One veterinary with five helpers can treat 250 pigs of 40 to 50 lb. weight in a day.

"To prevent itch, the hogs are all sprayed about once in six weeks with a mixture of three parts of kerosene and one part of turpentine."

b. Pneumonia.—Hogs also die from pneumonia, contracted from exposure to cold. At Worcester 78 hogs out of 1800 died from this cause during one month in the winter of 1906. In the Secaucus district of New Jersey the principal losses are from pneumonia. The preventive is proper housing and protection against bad weather.

c. Foot-and-Mouth Disease.—Hogs also contract the foot-and-mouth disease. At Providence and at Worcester, in March, 1915, all the hogs had to be killed on account of it. No remedy has yet been found (1918), and Government inspectors insist on killing all animals at a farm which is thus infected.

The experience at Worcester is described by Professor Bonnet, as follows:

"In February, 1915, the herd of swine at the Home Farm was visited by the dreaded hoof-and-mouth disease, which was probably carried by crows from an infected herd of cattle near-by to the hogs fed out of doors. Federal and State Authorities took charge of the quarantine and the killing of some 2360 animals. The Federal Government paid one-half the assessed value of the infected animals, and the State the other half. After killing, these animals were buried in pits with lime. Those not infected were killed for pork. The farm was not restocked until the following September. It is interesting to note that the disease did not infect the Home Farm herd of cattle. During this interval the garbage was dumped in a hollow on the farm and covered with loam. In June swarms of flies developed from this dump, but, by the use of trap, a kerosene-turpentine spray (3 to 1), and a creosote spray, they were destroyed and kept under control.

"After the hoof-and-mouth disease, great pains were taken to rid the premises of rats. Poison, traps, shooting, and 'building out' were all employed. Many of the older buildings were condemned by the Commission because they harbored so many rats. These rodents not only steal garbage, but may prove a menace to the herd should they become infected. The only remedy for controlling them is by persistently killing them in every way possible and building them out. Crows are also a menace to the herd, as Wor-

cester has discovered to her sorrow, and their presence on pig farms should be discouraged."

B. RESULTS IN PRACTICE

As already indicated, many kinds and sizes of hog farms for garbage disposal are operated in America. A few typical ones are described below.

1. Worcester, Mass.—(Population about 175,000.) Since 1872 some portions of the city garbage have been taken to the Home Farm and fed to hogs, and the Superintendent sent a wagon into the city to collect enough garbage to feed them. The work has developed with

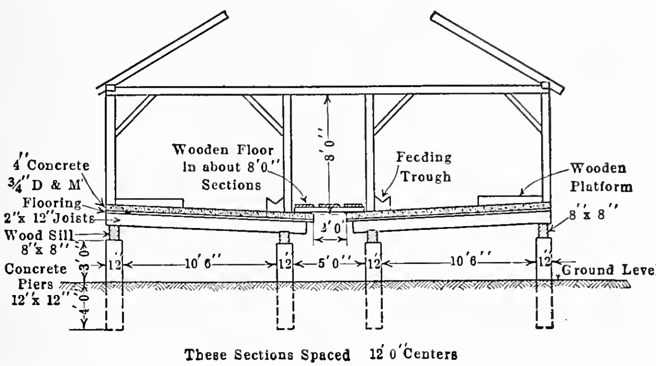


FIG. 66.—Typical Section through Hog House Proposed at Worcester, Mass.

the growth of the city, and in 1918, about 70% of the garbage of Worcester was taken to the Home Farm, where there were from 2000 to 3000 hogs. A special so-called scavenging department has now been organized to handle this work. The garbage not collected by this department is taken by private collectors, and is also largely fed to hogs.

The farm is in the northeastern section of the city, about 3.2 miles by road from the City Hall. On the left, the farm borders Lake Quinsigamond. The country is rolling, partly wooded, and has the gravelly open soil typical of the New England glacial drift. A brook which drains the farm empties into the upper end of the lake. The Home Farm proper covers 376 acres, but the city leases also an additional area of 220 acres at a rental of $1500 per year.

Fig. 66 shows a typical section through the pig house at Worcester proposed in 1916.

The garbage is collected in two-horse wagons, each holding approximately 2.5 cu. yd. Normally, there are 21 wagons in service, and each delivers one load a day. The garbage is removed twice a week from each house in the collection area. An unusually good separation is maintained by the householders, and comparatively little foreign matter is found in the garbage. Fish offal and rotten eggs from markets and commission houses are collected separately, in special cans with tight-fitting covers, and are buried, as they are not suitable food for hogs.

Until recently, most of the hotel, restaurant, and hospital garbage in Massachusetts cities was collected privately, but now the cities are exercising more authority in the matter (Chapter 75 of the Revised Laws, Rule 22), and are starting a public collection of garbage.

The garbage as it comes to the farm is neither washed nor steamed. Washing is not found to be economical because pieces of food are lost. Cooking or steaming was found by experience to be objectionable, as it made a soup from which the hog could not reject unsuitable food.

In practice, the little hogs are kept with their sow in individual pens until they are six weeks old, although they begin to eat garbage when about three weeks old. The boars are castrated when about five weeks old, and are then left with the mother another week. Hogs are kept in pens until about six months old, and are fed from troughs. At the end of this time they weigh from 75 to 100 lb.

After six months the hogs (or shoats) are turned into out-door lots, about 3 acres being required for 100 hogs. Here the garbage is spread on feeding platforms made of 2-in. plank in 8-ft. square sections. These are mounted on skids, and have half-round timbers on two sides to prevent the garbage from being pushed off. Several sections are placed end to end. When the ground around the platforms becomes fouled with the spilled garbage, the platforms are skidded to another location, and the used ground is plowed over. The platforms are shovel-cleaned daily. The hog manure and leavings are composted, and are sold in quantities weighing from 230 to 300 lb.

Hogs are bred by turning about 300 sows into the same lot with about 30 boars for about five weeks. The first period is from about October 20th to December 1st, which brings the farrowing during the latter part of January, through February, and into early March. After a month or six weeks, a second lot of hogs is bred, and so on. During farrowing, and sometmes during inoculation, they receive a little grain and middlings. Boars are rarely kept more than two years, and only the best sows are kept for repeated breeding.

Up to 1914 there were twelve hog houses scattered about the farm. Seven of these were shelter sheds for outside hogs, but they have since

been abandoned. At present four hog houses and two shelter sheds are in use. All the houses are arranged for feeding in the pens. One of the houses is steam-heated, and is used largely for farrowing and for treating the animals when sick. The most recently constructed house is of rat-proof construction, including concrete foundation walls, extending several feet above the ground, and having a rock-filled basement under the floor. To provide additional pens for late spring farrowing, 100 small portable take-down colony houses have been built.

Fig. 67.—Old Method of Unloading Garbage for Hogs on the Ground, at Worcester, in 1910.

There has been an interesting development in the feeding method at this farm. Formerly, the garbage was spread over the ground, Fig. 67. This was unsatisfactory because a considerable portion was trampled into the ground, where it was lost as food, and decomposed with a marked odor. Then the garbage was placed on platforms set out in the open, Fig. 68. This was an improvement, although some garbage was still spilled off the platforms and fell on the ground. In 1918 garbage was placed inside the hog houses and on the platforms, and this method gives full satisfaction. The pens are cleaned daily, and the cleanings, consisting of hog manure, urine, uneaten garbage, and soiled bedding, are removed to compost pits. If not properly treated, this material decomposes rapidly and produces

unpleasant odors. However, when properly composted in layers with equal quantities of dry top soil, the decomposition may be kept on an aerobic basis, without odors. Large concrete compost pits have been built at Worcester for this purpose. About 2.5 cu. yd. of this so-called "hog manure" are produced daily.

Experience further indicates a need for careful attention to the suppression of rats and flies. The proper measures include rat-proof construction of hog houses, proper disposal of hog manure and whatever garbage is not used for food, and a liberal use of germicides wher-

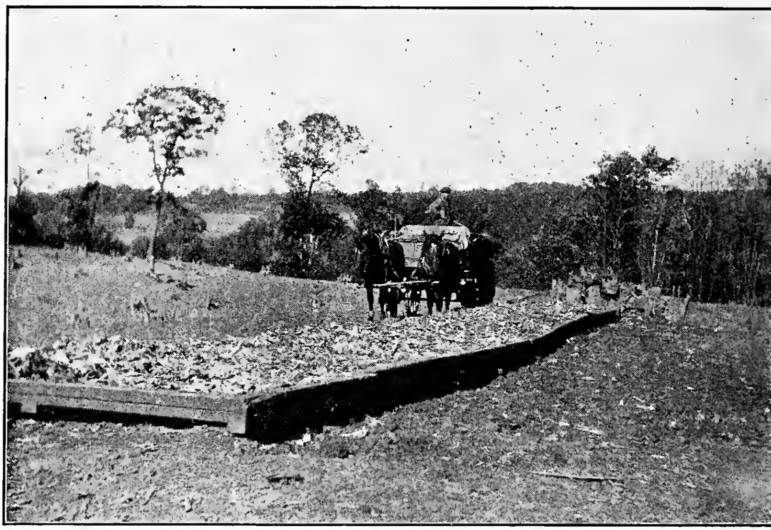


FIG. 68.—Unloading Garbage for Hogs on Platforms, at Worcester, 1914.

ever fly maggots appear. Burial areas and compost pits are quite desirable.

The Worcester hog farm has recently been well operated under the direction of Mr. Thomas Horn, under the advice of Professor Bonnet. It is found that one caretaker is needed to feed and bed each 250 to 300 hogs, and to clean the pens.

Cost data for the Worcester hog farm are presented in Tables 83 and 84, the data being largely taken from reports by Professor Bonnet. It should be noted that the cost records of the scavenger department at Worcester are so interwoven with those of the Poor Farm proper that a separate statement is not easily secured. Furthermore, land charges, rental of leased land, cost of colony houses, compost pits,

roadways, main fences, etc., are not included. The labor rates are given at very low figures, and appear on the whole to be too low for application elsewhere, irrespective even of the large advance since the beginning of the War.

TABLE 83.—COST OF A HOG FARM, BASED ON WORCESTER CONDITIONS, EXCLUSIVE OF LAND, AS ESTIMATED BY PROFESSOR BONNET (1917); AND OPERATING EXPENSES AT WORCESTER, EXCLUSIVE OF FIXED CHARGES

Capacity, 20 to 30 tons per day

(a INVESTMENT REQUIRED:			
Four buildings, capacity about 300 pens, 6 by 12 ft., including small heating plant for one house, water supply, drainage, platforms, and fencing			$30,000
Three horses, wagons, and sleds for disposal work			1,500
Stock 1100 hogs	at $30	$33,000	
100 sows	at 25	2,500	
800 shoats	at 12	9,600	
900 small hogs	at 5	4,500	
30 boars	at 20	600	
Totals, 2930		$50,200	$50,200
Total investment			$81,700
(b) OPERATING EXPENSES, EXCLUDING FIXED CHARGES			
Hog caretakers, 7			
Manure men, 2			
Compost man, 1			
— 10 at $37 per month			$4,440
Additional occasional help			1,320
Grain and bedding			2,640
Medicine (serum, virus, and disinfectants)			3,040
Superintendent, farm foreman, and office			2,560
Light, heat, water, etc			1,000
			$15,000

In more recent estimates (July, 1920), made for Toledo, Ohio, by Greeley, the first cost of a farm for 5000 hogs, embracing the items of land, farmhouse, shelters, feeding houses and platforms, barn, track, roadways, fencing, teams and wagons, water supply, and sewerage, is given at $150,000; and the annual cost for supervision, labor, feed, veterinary service, supplies, light, heat, water, new stock, loss

of stock, shipping and selling expenses, repairs, and legal and administrative matters at from $130,000 to $175,000, with fixed charges of $18,000.

Table 84.—Operating Data at Worcester Hog Farm Including Cost of Collection

Year	Garbage Collected per Day			Number of hogs, November 30th, each year	Financial Summaries for each Year			
	Loads	Cubic yards	Tons		Total expenditures*	Total receipts	Net cost	Net profit
1898	....	....	....	....	$14,804.34	$7,674.02	$7,130.32	
1899	....	....	....	....	17,109.00	10,641.52	6,467.48	
1900	19	52.8	....	....	17,751.21	11,947.91	5,767.30	
1901	19	52.8	....	....	18,935.86	13,933.03	5,002.83	
1902	19	52.8	....	....	18,765.03	18,766.99	....	$1.96
1903	19	52.8	....	....	18,140.57	11,941.55	6,199.02	
1904	21	57.5	....	....	22,326.02	7,327.00	14,999.02	
1905	21	57.5	....	....	20,515.83	12,539.20	7,976.63	
1906	21	57.5	31.5	....	23,525.49	19,321.00	4,204.49	
1907	....	....	....	2850	30,491.93	24,830.71	5,661.22	
1908	....	....	....	....	34,475.73	24,321.22	10,154.51	
1909	....	....	....	....	37,737.79	29,257.25	8,480.54	
1910	....	....	....	....	37,039.68	43,224.25	....	4184.57
1911	....	....	....	1388	41,121.74	25,579.58	15,542.16	
1912	....	....	....	2057	45,750.28	22,863.27	22,887.01	
1913	....	....	....	2167	53,109.10	38,376.11	14,732.99	
1914	....	....	28.4	2502	53,325.62	38,838.67	14,486.95	
1915	21	52.5	22.2	1300	55,718.43	39,994.36	15,724.07	
1916	21	....	23.0	†	57,680.03	16,692.99	40,987.04	
1917	19	42.0	21.0	2096	83,241.19	44,609.15	38,602.04	
1918	20	54.0	27.0	2750	79,413.32	50,559.60	28,853.72	
1919	20	66.0	33.0	3081	105,272.18	73,643.17	31,629.01	

* Total expenditures do not include fixed charges, but do include costs of collection.
† In 1916, the hoof-and-mouth disease wiped out the herd.

2. Stony Wold Sanatorium.—At this institution, in the Adirondacks, the garbage is collected daily. It is dumped into a caldron, brought to the boil, then cooled and covered until fed to the hogs. The length of haul is about $\frac{1}{4}$ mile. In October, 1912 (an average month), there were 100 hogs. Additional food is purchased from time to time to prepare the animals for killing, and for nourishing brood sows.

The Berkshire breed of hogs is raised, more or less mixed with plain hogs purchased from local farmers. Every two or three years, a registered Berkshire boar is purchased, each time from a different breeder, in order to keep the animals vigorous, and to avoid the supposed ill effects of inbreeding. A financial summary of four years'

operation is shown in Table 85. The data in this table come through the courtesy of Mr. R. S. Weston, who states that "Careful post mortem examinations of the swine have failed to disclose any lesions due to infection, and the experiment coincides with that of other corporations."

TABLE 85.—COST OF OPERATING THE HOG FARM AT STONY WOLD SANATORIUM

Item	Year			
	1909	1910	1911	1912
Value of stock on hand, January 1st	$ 497.75	$ 758.24	$1101.24	$1032.40
Expenses:				
Labor and supervision	390.68	555.11	613.44	673.11
Supplies	747.97	1073.81	1041.10	1652.72
Total debit	$1636.40	$2387.16	$2755.78	$3358.23
Stock on hand, December 31st	758.24	1101.24	1032.40	1390.05
Receipts from sales	1703.80	2211.04	1648.94	2310.66
Total credit	$2462.04	$3312.28	$2681.34	$3700.71
Profit	$825.64	$925.12	....	$342.48
Loss	....	....	$74.44	....

3. Lansing, Mich.—At Lansing the experience has been satisfactory, and, considering the investment, profitable. There are more than 400 hogs, valued at more than $12,000, and the intention is to double the plant. The garbage is placed on the ground, or on cement platforms. In the former case the land is subsequently plowed and a crop raised. The average hog eats 20 lb. per day, and, under good conditions, gains from $\frac{1}{2}$ to 1 lb. per day. The losses of animals are not serious. It is reported that some substances which have found their way into the garbage with bad results are the very thin glass from electric light bulbs, and also phonograph needles and discarded razor blades. Frozen garbage is unsatisfactory to feed, and requires thawing.

All hogs should be given a serum vaccination, and should have a weight of at least 100 lb. before being fed exclusively with garbage. Some losses are reported to be due to poisoning by decomposed food

and carelessness; some are due to muddy, clayey and wet grounds, which may produce pneumonia and retard the growth of the hogs.

The following is quoted from a bulletin of the U. S. Food Administration entitled " Garbage Utilization," issued in February, 1918.

> " The secret of success with garbage-fed hogs is, as with grain-fed hogs, largely one of management. The man behind the hogs is the prime consideration. It requires hard work, no little knowledge of hogs, and a large amount of common sense to raise garbage-fed hogs. Cities undertaking municipal hog-raising must remember that the pigs are to be fed on garbage; not on politics. The men who are making a success in this work are up early and late, are progressive, know their hogs, and have a distinct knowledge of what is being done and how it should be done."

The meat of garbage-fed hogs is equal to that of grain-fed animals, and, in fact, has brought the highest prices in the Detroit market.

4. Baltimore, Md.—On May 1, 1919, a 4½-year contract was let in Baltimore (estimated population 720,000), for disposing of the garbage (140 tons daily) by feeding it to hogs at a farm on the shore of Chesapeake Bay. The city pays the cost of collecting the garbage and towing it to the farm. The price per ton to be paid to the city, after delivery at the hog farm, a distance of sixteen miles by barges, is three and one-half times the top price per pound of live killing hogs at Chicago, the garbage to be drained before weighing. The city will enforce a good primary separation and the delivery of all household and hotel garbage and animal market refuse.

The farm (Fig. 69) covers 157 acres, and comprises concrete feeding platforms, buildings, and yards (May, 1920), for 5000 hogs. There are fourteen yards, each 100 by 500 ft., and each contains a small shelter house (34 by 80 ft.) having a capacity of from 300 to 350 200-lb. hogs, or from 500 to 600 100-lb. hogs. The feeding platform is of concrete, and the garbage is taken from the wharf in trains of 1-yd. cars on 24-in. gauge track, and unloaded by hand. The maximum quantity of garbage handled at the farm (up to May, 1920) was in July and August, 1919, and amounted to 120 tons per day.

As the city failed to deliver the garbage in a fresh condition, fit for feeding to hogs, the contractor has abandoned the contract.

5. Newark, N. J.—During 1919 a five-year contract was let for disposing of garbage by feeding to hogs. The price per ton to be paid to the city after delivery at the hog farm is eight times the top price per pound of live killing hogs at Chicago. Newark has a population (1920) of about 430,000, and garbage (separated from other refuse) is collected from about 300,000. It is collected three times a week from residences and daily from business houses, and amounts to 35 or 40 tons a day.

The farm is in the industrial district of the city, is surrounded with chemical, oil, and glue works, and is near a large city dump. It covers 8 acres of land, built up in the marshes with refuse, and covered with cinders. The farm is intended for intensive operation on a small area, and all the garbage is fed indoors (Fig. 70). There is a scale house, an office, four hog houses, and a barn within a fenced-in area. Each hog house is 100 ft. square, and has a central concrete feeding

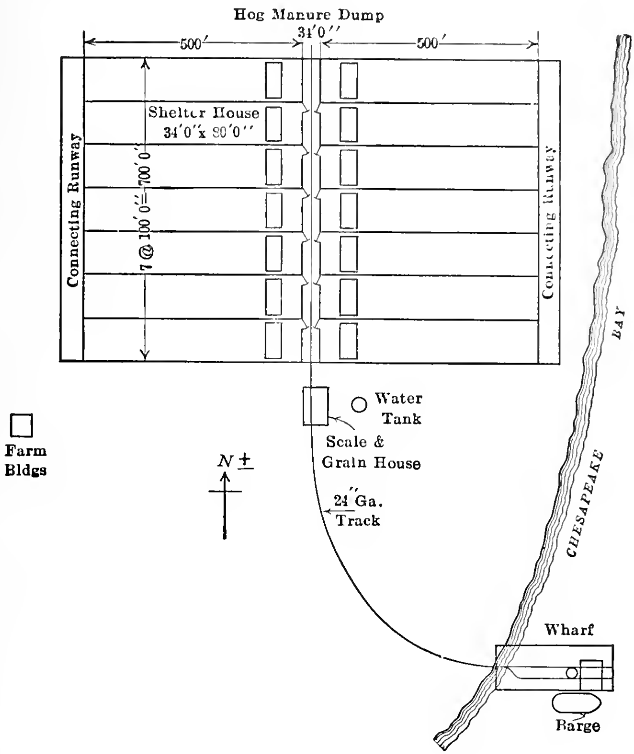


FIG. 69.—General Plan of Hog Farm, Baltimore, Md.

platform 24 ft. wide. Wagons are driven directly upon this platform and the garbage is spread on it. The pens have wooden floors, laid on concrete. Each building is supplied with water under pressure, and has a sewer. No heating is necessary. Each hog house has a capacity for 900 or 1000 animals. Experience indicates that the feeding platforms are too small and the pens too large.

The animals are allowed on the platforms once a day. Garbage

is the only food, except when no deliveries are made. The work is conducted by a foreman (who lives at the farm) and four men. The manure and leavings, amounting to about 50% of the garbage delivered, are cleaned off daily, and are dumped about the buildings and composted with lime. The manure is handled by two men with a

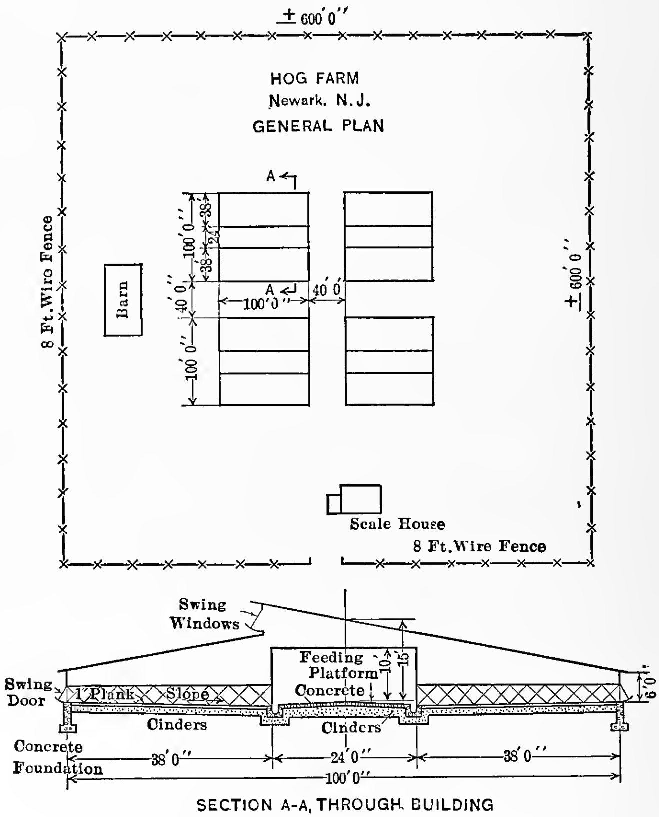


FIG. 70.—General Plan and Section of Hog Farm, Newark, N. J.

one-horse wagon. Negotiations are pending for shipping the manure to truck gardeners as fertilizer.

6. Denver, Colo.—At Denver the Hog Ranch Company collects and disposes of the garbage at no cost to the City. Collections are made daily in the down-town district and twice or three times a week in residential districts, except for a less frequent collection in cold weather. The farrowing shed is a wooden structure, 504 ft. long and

30 ft. wide, with 8- by 10-ft. pens on each side of a 10-ft. roadway. The inside pens are connected with open 8 by 16-ft. feeding pens. Garbage is shoveled directly from the truck wagons to the outside pens, there being driveways for this purpose on both sides of the shed. On the far side of each driveway there are 50 by 200-ft. "fattening" pens, where the garbage is placed on concrete platforms. There is a fence on each side of this platform, with gates to control the access of the hogs to the garbage (Figs. 71 and 72). Hogs that are being fattened will not entirely clean up the garbage. Lean pigs or recently bred sows are then let in on the feeding platforms, and every day the material finally left on them is cleaned off, put in wagons, and taken

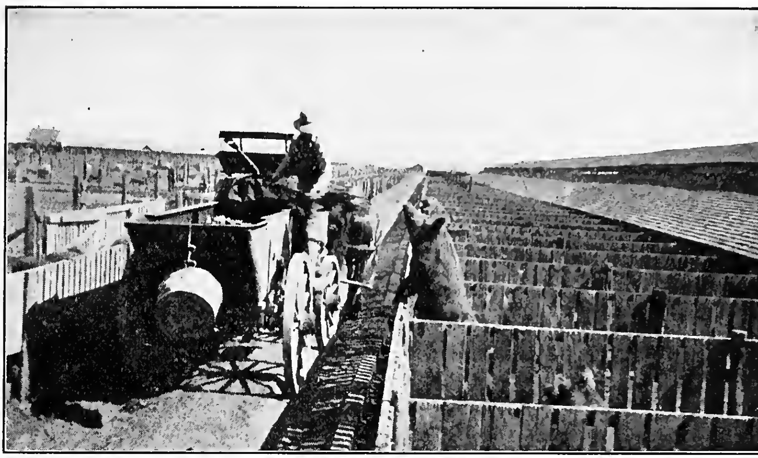


Fig 71.—Denver Hog Farm.

away. Garbage is not cooked at the Denver farm. Cooking was tried several years ago, because of an agitation against the feeding of raw garbage, and $20,000 was spent for a plant. The hogs did well on the cooked garbage for about two months, and then began to lose weight. Organic acids were said to have been formed by the process which at first stimulated the action of the stomach, but finally irritated it.

7. Grand Rapids, Mich.—Garbage has been fed to hogs at Grand Rapids for many years. The first farm (used until 1913) included an area of about 100 acres of sandy soil about 5 miles from the center of the city. The owner of the farm took the garbage from the city at loading stations and transferred it in water-tight freight cars to the farm. The transfer and disposal of garbage were at no cost to the City. A siding from the railroad extended about 1000 ft., between long open

feeding pens containing concrete platforms (Fig. 73). There were also three farrowing buildings to which garbage was delivered by wagon.

A new farm, 43 miles from Grand Rapids, has now been established, to which the garbage is delivered by freight cars. It covers an area of 240 acres, and at times contains as many as 6000 hogs. Garbage is fed on the ground and on concrete platforms. To handle the garbage of 135,000 people, seven freight cars a week are required, with an increase to eight cars a week in the summer. Garbage is collected three times a week during the eight warm months of the year and twice a week during cold weather. The free moisture is drained out at the

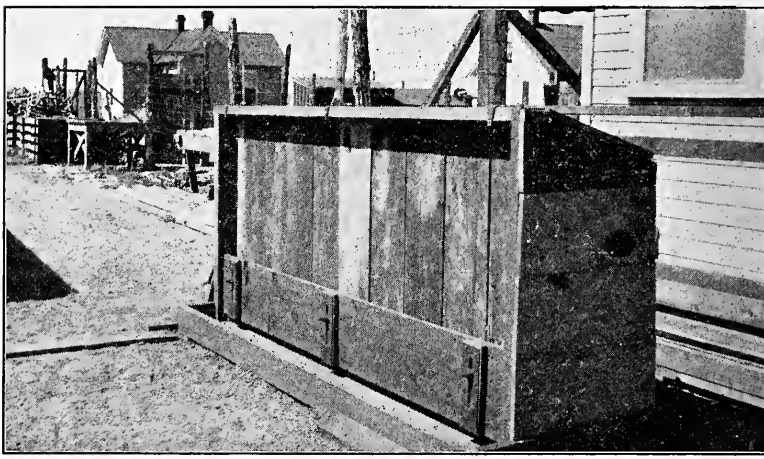


Fig. 72.—Feeding Box, Denver Hog Farm, Placed between Driveway and Pens.

transfer stations. It is stated that the unconsumed garbage does not amount to more than 10% by weight of the total raw material. The bones, picked out after the feeding, amount to from 500 to 600 lb. per day, and are worth 1 cent per pound (1918).

8. Salt Lake City, Utah.—The garbage is collected by the Mountain States Feeding Company, and transported to a feeding farm, about 7 miles north of the city. The farm comprises 60 acres, but only a small part of this area is as yet used. The main building, 70 ft. wide and 140 ft. long, and 48 colony houses, cover about 6 acres. Each colony house accommodates 50 hogs, and includes a 9 by 64-ft. shelter, a 9 by 64-ft. open feeding floor, and a 15 by 64-ft. runway. The hogs eat and sleep on board floors, and have never been troubled with rheumatism. Flowing wells supply fresh water which is conveyed

to a stand-pipe, from which it is piped to a trough at each colony house. Hose can be attached to the water system, thus providing fire protection for the wooden structures, and enabling the attendants to give the animals a shower bath in hot weather.

At first the company expected to buy brood sows and raise pigs, but this was soon found to be a disadvantage, and now it purchases "feeders" and "stockers," each weighing from 80 to 100 lb. Each

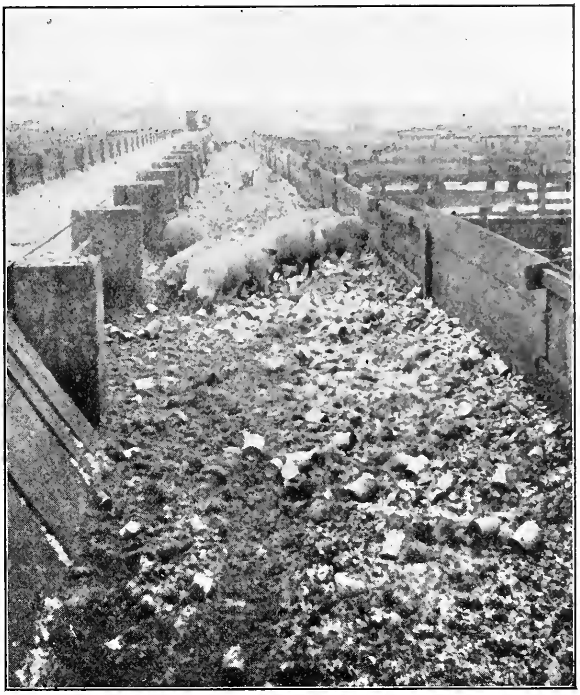


Fig. 73—Old Hog Farm, Grand Rapids, Mich.

hog eats from 15 to 20 lb. of garbage a day, and is also fed about 1 lb. of corn. This is said to give a daily gain on each hog of from $1\frac{1}{4}$ to $1\frac{3}{4}$ lb. Deducting from the haulage expense what the city pays for collection, the garbage costs the company about 5.6 cents a day for each hog.

Cooked garbage was tried, but, after thirty or forty days, the hogs did not relish it. Raw garbage is now used. In winter it is warmed by injecting steam into it.

Old hogs are double-treated with cholera serum before they enter the company's pens; and, before being allowed full feed, they are given what is called a " sweat period " of eighteen to twenty-one days. The company has never lost a hog treated in this way. As many as 2500 hogs are fed with garbage at one time, and the average number in the winter is 1500.

C. FOOD ADMINISTRATION CONFERENCE

In December, 1917, the United States Food Administration called a conference in Chicago of men experienced in the disposal of garbage by feeding it to hogs, in order to discuss the results which had been obtained in practice. Some of the more important findings are summarized as follows:

1. " **Quality of Pork Produced.**—If garbage-fed pork is inferior to grain-fed, the price paid by the packers, who are naturally averse to paying full price for an inferior article, should indicate the fact. We have not been able to find any market where garbage-fed hogs are being generally sold at a lower price than grain-fed animals. When cases of ' softer ' pork have been noted it has generally been found that the animals were improperly raised, kept in small pens, and not allowed to exercise. There is no theoretical reason why garbage should be bad for hogs. Even putrefying materials may be transformed into delicious human food; for example, lobsters, crabs, shrimp, etc., feed almost exclusively on decaying fish; and the common barnyard chicken will eat and thrive on almost all kinds of so-called filth.

" Recently, garbage-fed hogs were raised at the experimental station of a Middle Western State and marketed at the same time as hogs fed on corn and other grains. The carcasses of these garbage-fed hogs could not be distinguished by the officials of one of the large packing houses from corn-fed hogs, and were even given a higher grading than some of the hogs fed on certain grains.

* * * * * *

2. " **Gain in Weight per Pound of Garbage Eaten.**—A number of tests have been made which establish that a gain of about a pound per day can be expected with growing hogs. This means roughly that a ton of garbage is equal to 100 pounds of live weight gained. It does not mean, however, that tons of garbage as produced multiplied by 100 equals the live weight to be put on the market. A certain percentage of loss in stock is always to be expected, and even with the fullest co-operation with householders, city officials, etc., a certain amount of inedible material, and even inedible garbage, will always be present.

" Some feeders are stating that the quality of the garbage now produced is not as good as that of a year ago—that more garbage must be eaten to produce a pound gain. This is not definitely established, but it is reasonable to suppose that with high prices, etc., the quality is not as good. We recommend that. to cover losses and a possible decrease in the quality of the garbage

fed, the amount of marketable live weight be assumed at 1 lb. to 50 lb. of garbage. With careful management the ratio could be lowered considerably.

* * * * * *

3. "**Location of Farm.**—The distance of the farm from the municipality naturally depends on local conditions. With wagon or truck haulage, distance is an important factor, but with carload lots an additional 10-mile haul adds very little to the freight rate, and a more ideal location may be selected.

"The pig farm should be located on soil that drains readily, preferably sand or gravel. For the same reason it is advisable that the land be rolling; the houses should then be located for warmth in winter and coolness in summer. Good drainage is essential at all seasons.

"Garbage-fed hogs require abundant drinking water. If any streams or brooks are included in the property, they should be carefully traced and their purity established, or else fenced off so that the animals will drink pure water otherwise supplied.

"The size of the farm necessary varies with the system of handling. With feeding out of doors in all but extreme weather, assume 50 pigs per acre. Under cover, the number can be increased to from 400 to 600 per acre.

* * * * * *

4. "**Methods of Feeding.**—The two general methods of feeding depend primarily on how the material is delivered to the farm. When in wagonloads or by motor truck, it will probably be advantageous to have what are known as feeding lots. These lots are about an acre in size, and contain one or more feeding platforms made of lumber, and of sufficient size to hold a load of garbage as delivered. The platforms are on skids, and have a low rail, a 2 by 4-in., nailed on edge, to help prevent the garbage being shoved off the platform.

"The pigs are permitted to enter the feeding lot only after the garbage has been dumped and the vehicle has left the lot. This prevents injury during unloading and avoids garbage being thrown on the pigs.

"After feeding, the pigs are shut out of the lots, the bones gathered, the platforms cleaned and skidded to a new location. The ground beneath and around the old site is plowed under, and danger of odors from all spilled garbage or moisture eliminated. The feed lots are changed from time to time, and various forage crops grown on the lots thus fertilized by uneaten garbage and manure. This appreciation of the soil is important, and land that will benefit by such fertilization can well be purchased rather than land totally unsuited for tillage and the raising of crops.

"Where delivery is made in carload lots, the labor expense of rehandling may eat up a large part of the feed value. Under such conditions the hogs are brought to the garbage, and the feeding platforms are adjacent to the railroad tracks. Cement platforms soon become eaten by the acid in garbage, but some impervious material must be used where the platforms can not be moved about and the ground underneath turned over. The use of narrow troughs is objectionable. Not only do they become so eaten by the acid as to be hard to clean, but it is much better to spread the material out on a flat surface where the hog will have an opportunity to sort and reject any injurious matter.

"The best garbage should be fed to fattening stock or to sows with young

pigs. When open-lot feeding is practiced, this is a simple procedure, since the material collected in the better portions of the city can be reserved for these particular purposes. With carload lots the same effect is produced by first permitting only the fattening stock to the platforms. After these have become satisfied, a second lot, say, young shoats, are let in. In the same way a third or even a fourth lot are given an opportunity. Not only is the better garbage eaten by the most important portion of the stock, but the garbage is eaten more closely. The last lot, generally brood sows, are kept hungry and can be relied upon to clean up all the edible material remaining.

"The feeding of frozen garbage during the winter months is not considered advisable. It may be unavoidable, but it must be remembered that before this food can be digested its temperature must be raised to that of the stomach. This requires a certain amount of energy, more cheaply supplied by mechanical means than by the body heat of the animal. Considerable frozen garbage is being fed, but not as good gains in weight are obtained. Where the material is thawed before feeding, the gains are said to equal those of other seasons.

"All authorities agree that abundant fresh water must be available at all times. If possible, some sort of heater should be provided to prevent freezing during severe weather.

* * * * * *

5. " **Use of Supplementary Feeds.**—Most garbage is more or less a balanced ration and no supplementary feeds are required. We find, however, in a number of places, that animals are finished off with corn; in others wheat, middlings, or similar feed is given to brood sows, or corn silage is fed on Sundays. As a rule, however, no feed other than garbage is provided. Other feeds, and particularly pasturage, may cause gains to be made in quicker time. With hotel and other special garbage a certain amount of roughage may be desirable and even necessary. The opinions of different raisers vary greatly, with the personal qualifications of the man feeding providing the most important factor. No differences in results are claimed by those supplementing garbage as compared with those feeding garbage alone.

6. " **Amount to Feed.**—In using grain feeds it has been conclusively shown that greater gains can be made per pound when the feed is available to the animals at all times. The same result not unnaturally seems to hold with garbage feeding. It must be remembered that the percentage of water in garbage is much higher than in grain feed. The animal must, therefore, fill up oftener to obtain the same amount of sustaining matter. This means that the garbage must be available to the animals for a considerable portion of the day.

7. " **Cost of Feeding.**—The cost of operation at a farm depends almost entirely on conditions at the piggery in question; any comparisons would be misleading unless a careful analysis of all factors leading up to and depending on such costs were considered.

" In a general way it is safe to assume that the cost of disposal after the farm is reached, including overhead charges at the farm, would not exceed $3 per ton. Less costs are reported, and the above figure permits of reduction with careful management. A supplementary source of revenue at a farm is the

bones recovered. These are collected preparatory to cleaning up the platforms each day. The amount recovered runs from 75 to 100 lb. per ton of garbage.

8. " **Number of Animals per Pen.**—The losses due to ' piling up ' are so heavy that each hog raiser has very positive ideas as to the number of animals per pen. Some say that as low as 10 is the number to be allowed in a shelter.

" Individual pens should be provided for each brood sow, or at the most two sows should share the same pen. Upon being weaned the young pigs should be kept 8 or 10 to a pen until about eight or ten weeks old. Efforts should be made to keep in each pen pigs of approximately the same size. When over 60 to 75 lb. in weight they can be turned out into comparatively large lots. The larger the animals the more can be put together in a single inclosure without danger. Our records indicate that as high as 500 to 600 animals have been kept in a single inclosure without sufficient piling up to cause harm."

Some tests, at Louisville, on the feeding and growth of hogs showed that 32.4 lb. of city garbage were required to add 1 lb. to the weight of the animal. The tests lasted seven weeks, and from 25 to 40 hogs were under observation. With pork on the hoof at 15 cents per pound, the garbage would have a gross value of $9.26 per ton, but it was sold by the city at that time (September, 1918) at from $3.00 to $3.50 per ton. At Worcester it has been found that 37.5 lb. of garbage are required for each pound gained by the hogs. Hotel garbage has a higher food value, and, in St. Louis, it has been found that only 25 lb. of such garbage produced a gain of 1 lb. in the weight of the hog. This result has also been confirmed by tests at the Iowa Agricultural Experiment Station. With pork at 15 cents per pound, hotel garbage, for feeding purposes, should have a gross value of $12.00 per ton. From this gross value one must deduct the cost of plant operation, risk, overhead, etc., and such costs are quite variable. In Worcester, in 1916, the total annual cost was estimated at $2.30 per ton. Contractors, however, do not seem to be willing to pay much more than $1.00 per ton for city garbage, and in some cases less, some contract prices being as follows:

City	Year	Price paid by contractor to city per ton of garbage delivered
Minneapolis, Minn	1918	$1.26
Grand Rapids, Mich	1917	0.45
Portland, Ore	1918	3.90
Newark, N. J	1919	1.20*
St. Paul, Minn	1917	1.95
Anderson, Ind	1917	1.00

* Computed at eight times the pound price of live pork in Chicago.

Ordinarily, contractors agree to dispose of the garbage, exclusive of collection, free of cost to the municipality, or for a nominal sum. At Omaha the contractor paid the city a nominal sum. At South Bend an offer of $1 per ton was made for city garbage, including the hotel garbage, under a ten-year contract. At Denver the contractor collected and disposed of the garbage, a few years ago, at no cost to the city. In 1917 New York suburban farmers paid from 75 cents to $1 a ton for hotel garbage; in 1918 they paid from $1.38 to $3.27 a ton.

D. NUMBER OF HOGS REQUIRED

The number of hogs required to dispose of garbage from different populations varies, of course, with the season and other local considerations. The available data on this subject are presented in Table 82.

E. CHARACTER OF PORK

The quality of the hog meat should be judged by the following characteristics: Hardness, color, oiliness, and clearness. In other words, the meat should be hard, white, and free from oiliness and irregularities. Garbage-fed hogs compare favorably on this basis with others. At Worcester the loss from condemned meat has recently been less than 50 lb. in 100,000 lb., or 1 lb. per ton.

The principal difference between garbage-fed and grain-fed hogs is not in the quality of the meat, but in the yield of pork, which may be 10% less for those fed with garbage. Professor Evvard (Agricultural College, Ames, Iowa) found that garbage-fed hogs, dressing to 74.2 to 76.8%, will run about 3% below grain-fed hogs. Garbage-fed hogs will shrink about 5% in shipping. As regards the finished products, however, there is practically no difference.

F. CONSTRUCTION AND OPERATION

Construction and proper equipment are essential elements in the successful management of a hog farm. Where prevention of disease is so vital to a continuous service, economy demands that the greatest cleanliness be observed. The buildings should be substantial, well lighted, well ventilated, and have smooth concrete floors. Concrete, to resist gradual injury by weak acids, should be thoroughly dense, have a smooth surface, and not contain more cement than required to fill the pores of fine sand at the surface

The more buildings are provided for hog feeding, the less will be the likelihood of nuisance, and the smaller is the area of land that will suffice.

The roadways and feeding pens should also be of concrete. There should be plenty of water available for washing and flushing, and good sewerage. At large farms, corn kept in silos is used for feeding on Sundays and holidays, when no garbage is delivered.

Of particular importance is the additional establishment about the farm of a sanitary method of disposing of garbage which is not suitable for feeding. It can be buried in a proper soil (Chapter VII); or it can be burned in a furnace. Some method of disposing of tin cans, other than by dumping, is desirable (Chapter IX). A proper method of disposing of the manure of hogs is also necessary.

Experience at Worcester and at Highland Park indicates that hog manure and garbage not eaten may amount to from 30 to 50% of the quantity of garbage received. If the manure and waste is buried in furrows by plowing, followed by hand trimming or scraping, and allowance is made for re-use every two years, from 0.67 to 1 acre will be required for 1 ton of manure and waste per day.

Sanitary methods of operating hog farms are essential. No garbage should be delivered unless it is fresh, and every part of the works should be kept thoroughly clean at all times. Compared with other methods of disposal, the delivery of clean garbage to farmers for feeding is quite satisfactory. The State should keep a record of the sanitary condition of the garbage farms, and any poorly kept farm should be either at once improved or abandoned.

The odors from garbage when it is fed in buildings do not usually extend more than about 150 ft., and 300 ft. is a reasonably safe margin.

It is advisable to provide sufficient area to grow corn for feed, and to build silos for its storage. Provision should also be made for warming parts of the garbage in winter. Good receiving and shipping facilities are essential.

The costs of construction and operation of the Worcester and Stony Wold Sanatorium farms have been given.

Cost data for the construction of hog farms are available in only a few cases. An estimate of cost made by Greeley in 1916 for a farm for Winnetka and Glencoe, to have 330 hogs and serve a population of 9000, is shown in Table 86.

At Danville a farm was planned for inside feeding, the design of the hog houses being shown in Fig. 74. Table 83 shows the operating data of the Worcester hog farm.

Fig. 75 is a design for a hog farm suggested in Circular No. 80 of

TABLE 86.—ESTIMATED COST OF CONSTRUCTION OF A HOG FARM AT WINNETKA, ILL., IN 1913

Population served, 9000

330 hogs at $5	$ 1,650
Horses and harness	1,000
Boiler house and sterilizing equipment	5,000
Buildings, pens, and fences	10 000
Farm house	3,000
Water supply	2,350
Railroad siding	1 000
Land, 10 acres, at $300	3,000
	$27,000
Engineering and contingencies	3,000
Total	$30,000

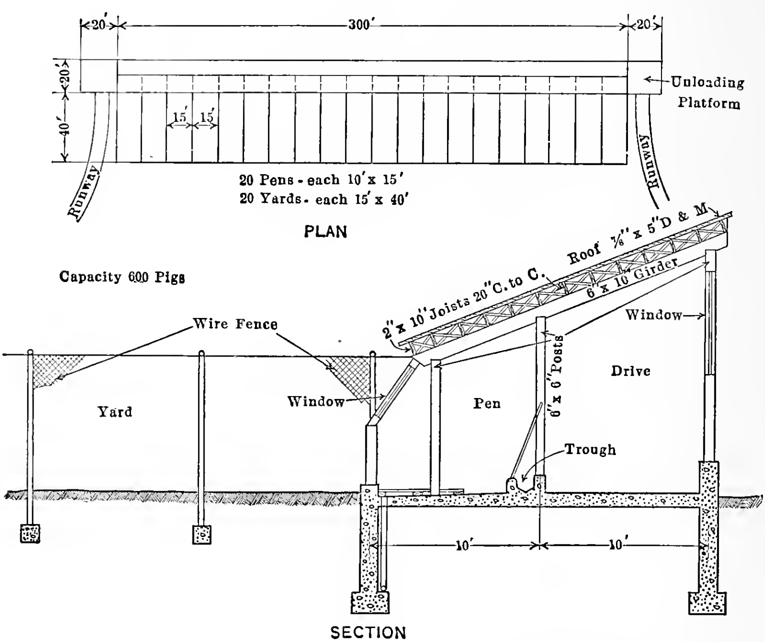


FIG. 74.—Proposed Hog House, Danville, Ill.

the United States Department of Agriculture, from which circular the following brief description is abstracted.

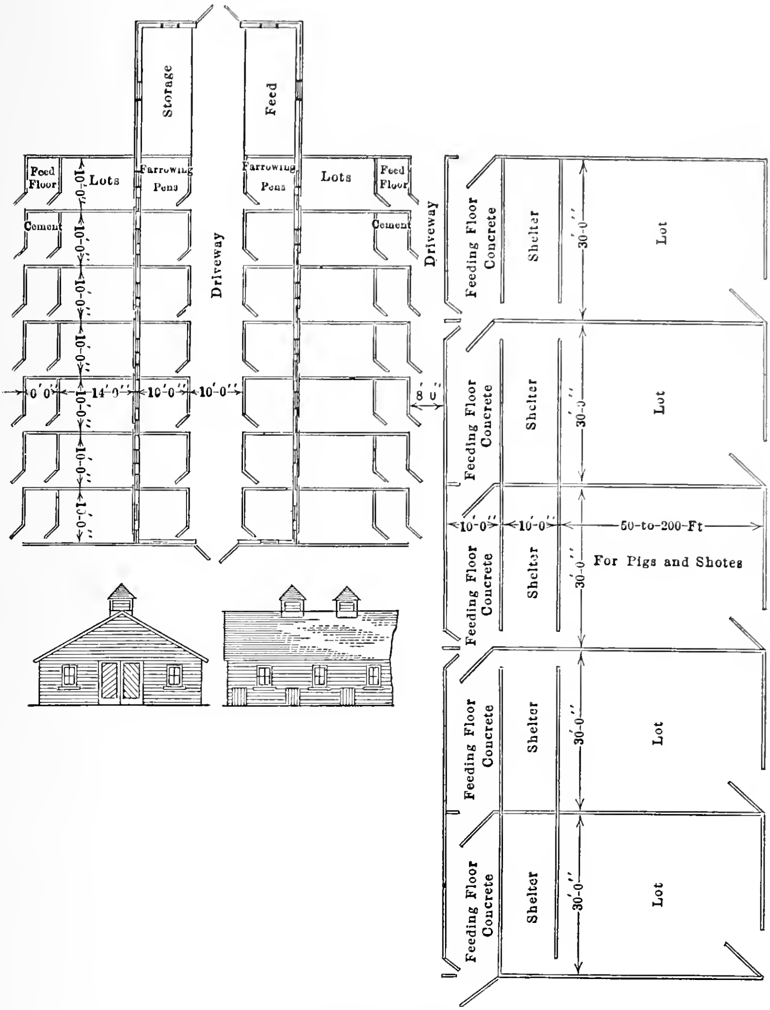


Fig. 75.—Suggested Design for a Hog Farm.

(From Circular No. 80, U. S. Dept. Agriculture, 1916).

The feeding pens are generally placed side by side, fronting a central driveway, through which the garbage is hauled. The pens should have a concrete feeding floor which should be surrounded with

a run. Some feeders prefer troughs. Plank flooring is undesirable, as it is almost impossible to keep it clean.

The sleeping quarters may be built just back of the feeding floor. Each pen should have a plot, or, if possible, a pasture, in order to provide a place for exercise, and here, in some cases, it may be possible to supply the hogs with a crop of rape seed, soy beans, or other green forage. The pens should have gates so that wagons may be driven through, in order to facilitate cleaning and the movement of the animals, and these gates should be arranged so that the hogs can be shut off the feeding floors while the garbage is being dumped in, and also while the floors are being cleaned. In the plan shown, the gates are arranged so that wagons may pass across all the feeding floors except those of the farrowing pens, in order to clean the floors and the shelters at the same time.

The pens for fattening hogs and for young stock are of various sizes because it has been found practicable to keep fattening hogs and brood sows in larger numbers than are safe for young stock.

In this design the farrowing pens and lots are placed between the pens and lots intended for other stock. Such a plan is convenient for a large establishment, but, if hogs are purchased and fattened and no stock is raised, the central building may be omitted and the fattening pens built on each side of a central driveway.

The plan is not intended to fit every case, nor is it complete in all details. The scale and system of operation, topography, available capital, convenience, etc., are factors which should determine the arrangement of pens, houses, and other equipment.

G. ADVANTAGES AND DISADVANTAGES

Apparently, there is quite a difference of opinion as to the sanitary features of garbage disposal by feeding. Some authorities consider the process a thoroughly sanitary one, and recommend it because of its comparative economy. Some few have opposed the process as a nuisance and as unsanitary. The authors share the following publicly expressed opinions, provided the garbage is fed while fresh and the works are carefully and properly designed, built, and managed.

a. Dr. Charles V. Chapin, Health Commissioner, Providence, R. I., in his annual report for 1902, states that " Feeding garbage to swine will not cause disease either in Providence or in other towns to which it is removed. In an experience of nineteen years I have never found a case of sickness that could be thus explained."

b. Dr. F. M. Koon,* of the Michigan State Board of Health, in 1912, when describing the Grand Rapids hog farm, states that "Everything is well kept and orderly. It seems that the City of Grand Rapids is disposing of its garbage and waste in an economical and satisfactory way. I conclude by saying that the garbage of this city is disposed of cheaply, satisfactorily, and in a sanitary manner."

c. Dr. Edward Cahill, of the Massachusetts Bureau of Animal Industry, states that 95% of all the hogs of Massachusetts are fed on garbage, with generally satisfactory results.

The general advantages of garbage disposal by feeding to hogs may be stated as follows:

1. The annual cost is low, compared with most other methods of disposal, particularly for the smaller cities and towns, with populations of less than about 75,000, and often a profit can be returned to the city.

2. As hog farms are generally at some distance from the community, and often at several comparatively remote individual farms, they afford a disposal which, because remote, does not require continuous supervision by the municipality. In small communities, the operation may be comparatively simple.

3. Garbage fed to hogs must be reasonably fresh, and therefore must be collected frequently. This is an advantage, because it demands the best possible collection service.

The disadvantages may be stated as follows:

1. The danger of losing hogs by disease is always present. Should many of the hogs die, the regular method of garbage disposal would be seriously crippled. This result would be more serious in a large than in a small city.

2. In some localities the comparatively large farm area required near-by is not available.

3. The practice of allowing a large number of farmers to collect garbage in a city, for feeding to hogs, makes supervision difficult.

H. SPECIFICATIONS

Although the municipal operation of hog farms may frequently be preferable, under favorable conditions, it will be advantageous at present in many cities to entrust this method of disposal to a contractor. It then becomes necessary for the city to embody suitable specifications in the contract.

Heretofore, specifications for garbage disposal by feeding to hogs have been very general in statement. They should generally include

* *Public Health*, Lansing, Mich., for January–March, 1912

a more definite description of the character of the structures to be built at the farm, and sufficient to insure sanitary operation. The specifications should not be limited to a general requirement for sanitary upkeep and operation, but the necessary works and apparatus to secure the cleanliness and healthfulness of the hogs should be specified with as much detail as practicable.

In 1906 a contract was made between Grand Rapids, Mich., and the Utilization Company, which is summarized as follows:

1. The city is to collect the garbage, tin cans, and unbroken bottles, and deliver them daily to the contractor.
2. The contractor is to dispose of the materials thus delivered in a sanitary manner outside of the city limits.
3. The delivery of the collected materials is to be made to the contractor in his vehicles or, at such convenient places as may be agreed on, where it can be loaded on these vehicles without expense to the contractor.
4. Garbage shall be held to include waste or decayed fruit, animal and vegetable matter, liquid and otherwise, which attends the preparation, use, cooking, dealing in, or storing of, meat, fish, fowl, fruit, or vegetable matter of all kinds, whether from private or public houses or manufactories, but not ashes, manure, night-soil, or rubbish.
5. The city agrees to make collections not less than twice each week, except that from November 15th to March 15th in each year the collections will not be oftener than once each week.
6. The delivery of materials shall be under the management of the Board of Health of the city.
7. The points of delivery shall be selected by mutual agreement between the city and the contractor.
8. The contractor agrees to dispose of the garbage free of cost to the city.
9. The contractor agrees to conduct the business of disposing of the garbage in a careful manner, and to observe any rules and regulations that may be made by any competent authority in reference to its sanitary disposal; and the work of removing it from the city shall be done in a manner satisfactory to the Board of Health.

The contract, made in 1908 at Denver, requires that the garbage shall be disposed of by feeding to hogs or otherwise, as fast as accumulated. For the protection of the City, the contractor should be bonded against unsanitary operation.

I. SUMMARY AND CONCLUSIONS

The disposal of garbage by feeding to hogs is an old standard practice, and utilizes the food value, which is its greatest value, unless the time and the expense of taking it from house to farm, before it becomes uneatable, is too great. Therefore, it is specially adapted

to small cities, towns, and villages; or by special daily collections also from hotels and eating houses in large cities.

To utilize its greatest value it is necessary at the house to keep the garbage thoroughly well separated from all other refuse, and to have frequent collections, from two to six or seven times a week, according to character of district, season, and general climate. It is also necessary to have suitably designed, well-managed, and thoroughly clean feeding establishments. The management should include an expert capable of taking care of the sanitary conditions of the food from the time of collection to the time of feeding, and able to combat hog cholera or other diseases, should they appear. This care is important, because a neglected farm is likely to have unfortunate results. Whether the garbage is collected and disposed of by contract or city forces, a thoroughly well organized supervision is essential for success.

Farms should be kept as free as possible from rats and flies by properly planning all structures and by a free use of traps. Incinerators, burial areas, or compost pits for all unconsumed garbage are necessary.

Cooking or warming the garbage just before feeding has here and there met with success, particularly when the garbage was stale. The quality of the pork produced on the best-managed garbage-feeding farms has been fully equal to that secured by corn-feeding.

The most serious drawback in hog feeding with garbage has been the difficulty of obtaining in all localities reliably tested and standardized serum and virus for inoculation against cholera, which produces immunity; yet this difficulty is being gradually removed. Pneumonia, which has occasionally visited the farms, can be prevented by proper housing and protection from the influence of bad weather. Against the foot-and-mouth disease there does not seem to be a reliable remedy, as yet.

A hog farm should be established on a well-drained and, preferably, a sandy or gravelly soil. The houses should be built for warmth in winter and coolness in summer. Plenty of water should be available for drinking and cleansing. All unconsumed food and all excreta should be removed and disposed of frequently and thoroughly, and the feeding platforms should be washed before the next feeding.

CHAPTER IX

SORTING RUBBISH

All classes of municipal refuse contain some articles which may be picked out, sorted, and sold. Rubbish, much more than other kinds of refuse, contains such articles as paper, rags, rubber, bottles, tin cans, bits of metal, old shoes, etc. At disposal works, laborers occasionally find silver spoons, coins, jewels, and other valuables in the collected material.

Picking over this rubbish, and marketing the salable portions, is an old custom, and is practiced with many variations. In Paris, members of the historic company of "Rag-pickers" (*Chiffoniers*) examine the house cans before collection, and take out that which they can use or sell. They remove from the refuse all materials that have any value before it is collected for final disposal. Therefore, there is very little material left to be picked out at the delivery point. It is estimated that the annual receipts of this ambulating Parisian rubbish picking establishment have amounted to many thousands of dollars.

Some picking over or scavenging is done at most of the refuse dumps in American cities by unlicensed scavengers, and frequently without municipal supervision. It is generally an unsightly activity, because the pickers are often slovenly and unclean, and allow small children to assist them. Under proper control, however, this work at dumps may be fairly satisfactory and bring a substantial revenue to the municipality. The total weight of rubbish systematically picked out and sold has occasionally ranged from 30 to 50% of the total rubbish collected.

The practice of sorting is not complicated, but it is open to the uncontrollable danger of transmitting diseases through germs in sweepings, bedding, and discarded materials from rooms where patients having infectious diseases have been confined.

The collection service should be arranged so as to bring the rubbish to the sorting plant in as dry and clean a condition as practicable, in order that the recovery may be worth while, and the ordinary second-

hand value of the materials approached as nearly as possible. The layout of conveyors, presses, and other machinery at the plant should be arranged so that the operators can work with the greatest efficiency and with as little lost motion as possible. Clean and sanitary conditions should be maintained everywhere, and good ventilation is essential. Most of the machinery required is on the market, and can be arranged and erected to suit each layout. The plant in large cities should be near a railroad, in order to facilitate shipments of the recovered materials.

A. DESIGN AND CONSTRUCTION

When carefully developed, the sorting is carried on in buildings fitted with conveyors on which the rubbish is spread out before the pickers. There are also bins for temporary storage, and presses and other machinery for preparing the sorted materials for shipment. An incinerator usually adjoins the building, and in it the residue is burned.

The design of a rubbish sorting plant involves first, a decision as to the extent to which the recovery shall be carried, then a selection of the machinery, and finally the arrangement of the parts so as to promote efficient and sanitary operation. The various parts are described in this chapter.

1. Receiving Arrangements.—Rubbish, weighing only about 200 lb. per cubic yard, has a comparatively large volume. The per capita production varies considerably in different cities. In Buffalo it amounts to as much as 68 lb. per capita per year. The quantity delivered each day to the sorting plant averages 50 tons, or, at times, more than 500 cu. yd. Owing to this large volume, ample space must be provided for unloading and handling it. The collection wagons ordinarily drive on a dumping platform in the building. The dumped material is then raked by hand to a sorting conveyor. A hopper is sometimes placed over the conveyor (Rochester) to facilitate the raking.

2. Conveyors.—When the volume of rubbish is large, the conveyor must be long enough to permit of spreading it out in a thin layer so that all pieces may be seen by the pickers. At Fort Hill Wharf, Boston, the conveyor is 100 ft. long. The belt should be of such a width that the pickers on each side may reach to the center conveniently. It is generally made of steel slats running on endless chains on each side.

The conveyor usually moves up an incline, and carries the rubbish to the sorting platforms placed on each side. At the Delancey Street

plant, New York City, the conveyor was of the apron type, 48 in. wide, with side angles to confine the rubbish. The slats were each 6 in. wide, extending entirely across the belt and lapping over one another, so that there was no open space between them when they traveled over the head-shafts. The speed was about 60 ft. per minute.

3. Storage Bins.—A storage bin must be provided for each kind and grade of material to be sorted. The bins are commonly arranged in two rows, one on each side of the conveyor, and are separated from it by the platforms on which the pickers stand. They are usually in the second story of the building, and discharge by gravity to the baling presses below. The bins for glass, iron, leather, twine, etc., should also be on the second floor, in order to permit of spouting the materials into cars or wagons. The capacity of the bins depends on the nature of the material and the schedule of operations. Each paper bin should hold about 2 cu. yd.

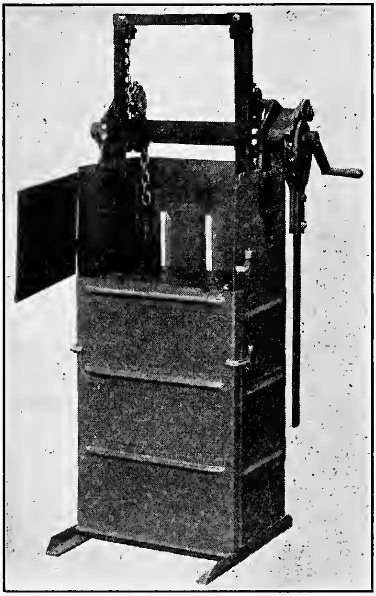


Fig. 76.—The "Pak-tite" Baling Press.

4. Baling Presses.—A baling press consists of a wooden or steel casing set in a heavy frame, within which there are pistons which may be operated by hand, through gears, or by a belt- or gear-connected motor. A large-sized press is 4 ft. 6 in. by 2 ft. 3 in. in plan, and 6 ft. deep, and can turn out a bale of waste paper weighing from 500 to 800 lb. A press of this type, motor-driven, cost in 1914 about $650, f.o.b. at the works, and weighed about 7000 lb. A smaller hand-operated press is 2 ft. by 2 ft. 6 in. in plan, 6 ft. deep, and makes a bale about 4 ft. deep. A press of this type, when built of wood, cost in 1914 about $100, and when of steel about $175, f.o.b. at the works.

Another type (Fig. 76) called the "Pak-tite" is manufactured at the Battle Creek Stamping Works, and the following details were given in June, 1917:

Size of bale	Weight of bale	Weight of machine	Price
14 by 18 by 30 in.	75 to 100 lb.	150 lb.	$28
16 by 20 by 32 in.	100 to 150 lb.	190 lb.	35
20 by 24 by 34 in.	200 to 300 lb.	275 lb.	50

5. Tin Can Presses.—The disposal of tin cans is a serious problem, both in small towns and large cities, and especially in the western part of the United States and in Canada, where large quantities of canned foods are used. Pressing the cans into small bales after cleansing them is a good method of marketing them, whether or not the other rubbish is sorted.

A satisfactory tin can press, operated by hydraulic pressure, has been made by R. D. Wood and Company, of Philadelphia. It consists of a heavy steel receiving hopper, one side of which acts as the head or plunger of the hydraulically operated piston. The hopper is filled with cans and the top is bolted into place before pressing begins. Attached to the same base plate as the hopper is the hydraulic cylinder, working under a maximum pressure of 4000 lb. per square inch. It is operated from a general hydraulic pressure system, or by a hand-power pump. The base plate is 5 ft. 4 in. long and 2 ft. 8 in. wide, and the height is 3 ft. 7½ in. The total weight is 8000 lb. The press costs approximately $650, exclusive of the pump. A small hand-pump costs about $50. A high-power baling press for tins is made also by Logeman Brothers, of Milwaukee.

Several tin can presses are in use in England. At Blackpool, the cost of labor for pressing and loading the baled tins into trucks was about $1.75 per ton. At Bradford, the Cleansing Department disposed of about 170 tons of tin cans per year, at an average price of about $3.75 per ton, f.o.b. at the works.

Tin cans are also treated by de-tinning. In 1916 de-tinning works at East Chicago, Ind., paid $5 per ton for tins delivered on freight cars. The process consists of a drying and cleaning of the tins and a recovery of the metal by heat and treatment with chemicals, as described later in this chapter.

6. Punching Machines.—Tin cans can be slit open and flattened out in a so-called " Disrupting Machine." The flat pieces of tin punched out are sold as roofing washers or crate corners. A disrupting machine is about 3 by 4 ft. in plan, weighs about 1000 lb., and requires about 3 h.p. for its operation. It can cut up about 8000 cans in an eight-hour day. The roofing washers or crate corners are

punched out of the tin cans with a No. 19 Bliss press, fitted with special, double-roll feed, dies, die blocks, and punch holder. These machines are made by the Asbestos Protected Metal Company, of Beaver Falls, Pa. Prices quoted, f.o.b. works (1914), were approximately as follows:

Disrupting machine	$350
Bliss press	165
Double-roll feed	150
Dies, die blocks, and punch holder	160
Total	$825

In addition, the company, in 1915, charged a royalty of $2 per ton of cans cut, or would take the cut and straightened tin for $15 per ton delivered at its works, in which case no royalty was charged. There is less waste in making crate corners than in making roofing washers. Each brought about 3 cents per pound.

7. De-soldering and De-tinning.—An apparatus for de-soldering, cleaning, and de-tinning tin cans was in operation at the London Electric Works, in England, in 1913, and is described by Goodrich as follows:

The tins are first sorted out and delivered to a perforating machine which punches the tins full of small holes so that the liquid used later in the process can penetrate more thoroughly. The perforated tins are delivered to a conveyor which discharges them into a perforated drum, revolving in a weak solution of hot caustic soda. This treatment requires about one hour, and cleans the tins of fat, paper, dust, bits of garbage, and other foreign material. The cleaned cans are discharged into a second and similar drum which revolves in an empty tank. In this, the entrained liquor is drained out. The tins then pass into a third drum revolving in cold water. From the cold-water drum they pass into a fourth drum, through which the waste gases from the de-soldering furnace pass, so that the tins are thoroughly dried. The tins now pass into a fifth drum, in which the de-soldering takes place. This drum revolves in an iron casing, and is heated to a temperature just high enough to melt the solder off the tins. The end of this drum is open, and discharges the de-soldered tins on a platform under which is a hydraulic press by which they are pressed into briquettes.

These briquettes were then shipped to Essen, Germany, to be de-tinned by what is known as the " chlorine " process, as follows: The de-soldered tin briquettes are put into a large iron cylinder from which the air is exhausted. The cylinder is then filled with pure

chlorine gas under pressure. The chlorine unites with the tin, forming chloride of tin ($SnCl_4$) for which there is a market in the silk-dyeing industry. This treatment frees the briquettes from all tin, and pure steel remains, for which there is a demand at the neighboring steel works.

At the London works about 15,000 tons of tins were made into briquettes each year, and at Essen upwards of 80,000 tons were annually de-tinned.

8. Storage and Shipment.—It is not generally advisable to provide sufficient storage to hold products over a period of low prices. There should be sufficient space, however, to tide over the usual irregularities in freight service. Arrangements should be made at the plant for the easy loading of cars, and as much by gravity as possible.

9. Buildings and Grounds.—Well-lighted buildings of brick or concrete are desirable. There is apt to be considerable dust from the handling of the rubbish, so that the building should be sufficiently high, and provided with good ventilation. All the work should be done within the building. The plant should be near a railroad, in order to facilitate shipping, and if the grounds are enclosed by a fence it will prevent loose papers from being blown away.

B. RECOVERABLE MATERIALS

1. Uses.—Efforts to save and utilize waste products should be encouraged only when the operation is economically justified and is not unsanitary, and rubbish sorting plants should be considered only from this point of view.

The United States is the chief paper-producing country in the world. In 1909 the annual output was estimated to be 4,216,708 tons. The consumption amounted to about 100 lb. per capita per year. Nearly half of this is used for newspapers and periodicals. Different substances can be used in manufacturing paper stock. Of these materials, of course, the soft woods, such as spruce, poplar, willow, fir, birch, and the like, are best suited, but waste paper and rags are also readily adapted to this use. The pulp-making portion of the trees amounts to less than 40% of the whole bulk, so that the waste is large.

It is estimated that one edition of a large Sunday newspaper needs 20 acres of wood-pulp trees, and that more than 2000 acres annually are required to furnish the pulp for the paper of one large newspaper. The drain on the forests of the country is evident, and the future economic value of saving marketable paper waste should

be considered carefully. The United States Department of Commerce summarizes the uses of such waste material as follows:

"Clean white cotton or linen rags and clean unbleached cotton and linen rags are always in demand. Scraps and small pieces are just as suitable as much larger pieces. The finest grades of paper are made from such material, and the demand for such rags is always steady.

"Cuttings from fancy shirtings, table damasks, toweling, cotton and linen dress goods, etc., are in demand, and are readily sold.

"Soiled white rags, both new and used, enter into the composition of a very large variety of high-grade white and colored papers.

"Soiled and dirty colored rags, known to the mills as 'thirds and blues,' except the black and dark-red colored ones, make up the largest amount of any single grade of rags used in the manufacture of high-grade book papers and medium-grade writing papers. In this class is included old canvas, awnings, sailcloth, and all kinds of soiled rags. No light-colored rag is too dirty to be used, as the manufacturing process converts the dirtiest rags into a white mass, whiter than the original cotton from which it was made.

"Black rags, especially old black stockings, are in general demand. They are used in producing black papers, and especially for mixing with lighter-colored paper stocks, thereby producing the effect known as granite papers.

"Woolen rags of all kinds are of value; the higher grades are returned to the woolen mill for re-manufacture, while the lower grades are in demand for manufacture into roofing papers or roofing felts.

"Attention is especially called to the wide range of uses for which rags and old papers of all kinds are available. All grades should be saved, as the rag picker and the paper maker will find a use for them. The highest grades will go into the higher grades of paper, while even the lowest grades of this waste material can be made into box board. The product known as box board is an excellent substitute for wood used in the manufacture of wooden boxes, and, when made into shipping containers, it is fully as strong as, and very much lighter than, the wood which it replaces. The saving of this material, therefore, produces a new and superior product, and at the same time conserves our forests.

"White clippings and shavings from book papers, bond papers, ledger papers, and writing papers, are especially valuable, and a steady demand for such material is always found.

"Printers' waste, consisting of paper damaged in printing, paper used to clean ink from the inked forms and rollers of printing presses, and other soiled printing waste, is available for re-manufacture into many different grades of paper.

"White and colored writing papers are suitable for re-manufacture into many other grades after the ink and coloring matter are removed.

"Clean wrapping papers of all kinds are valuable for re-manufacture into similar grades.

"Old books, magazines, periodicals, account books, etc., can be re-manufactured into book papers of excellent quality. All material of this kind that

is saved is of direct benefit to the forests of the country, as magazine and book papers are very largely made from wood pulps.

"Clean folded newspaper stock is suitable for a number of paper products, and is in demand.

"All grades of cardboard, strawboard, corrugated box board, and soiled wrapping papers, newspapers, etc., are suitable and in demand for re-manufacture into cardboard required to make containers for packing crackers, cereals, and other food products. The process of re-manufacture is such that the material used is thoroughly sterilized. The demand for clean food products requires that all old papers should be saved.

"Burlap bagging and manila rope are also of value in the production of strong wrapping papers, and the supply of this material is always less than the demand."

2. Market Values.—We give below, to serve as a general guide in forming an opinion, the market values that have prevailed in several American cities. The great war has altered many of them. Some are now higher, some lower.

A substantial revenue from refuse has been derived in Boston, New York, and other cities. In the latter city the privilege of picking over the refuse at the dumps and transfer stations is said to have netted an annual income of more than $100,000. In Seattle the mixed refuse is picked over on the dumps by city employees.

Relating to Chicago, we give the following figures:

The process of picking involves a separation of the waste paper into different grades, classified by their market value, as follows, the prices being those of the Chicago market in 1913:

Mixed or scrap paper	$ 7.00	per ton
Newspapers	8.00	"
Office records	10.00	"
Manila paper	10.00	"
Magazines, journals, and books with covers removed	12.00	"
Cardboard	5.00	"

Glass is separated into two classes, old bottles and broken glass, called "cullet" in the trade. Prices in Chicago in 1913 were as follows:

Flint or white cullet	$ 5.00	per ton
Light green cullet	4.50	"
Amber cullet	3.00	"
Whole bottles	0.30	per dozen

The prices of some other waste materials at Chicago in October, 1916, were as follows:

Scrap iron:	Per net ton
No. 1 cast scrap	$12.25 to $12.75
Stove plate and light cast scrap	10.75 to 11.00
Grate bars	10.25 to 10.50
Brake shoes	10.00 to 10.50
Railroad malleable	12.00 to 12.50
Agricultural malleable	11.00 to 11.50
Unassorted	About 8.00

Old metals:	Cents per lb.
Heavy wire	22.50
Heavy copper	22.50
Copper bottoms	20.00
Copper clip	21.00
Red brass	19.00
Yellow brass, heavy	14.50
Yellow brass, borings	14.00
Red brass, borings	16.50
Lead pipe	5.75
Tea lead	5.00
Tin foil	33.00
Block-tin pipe	35.00
Pewter No. 1	28.00
Scrap zinc	7.00
Tin cans when reasonably bright	3.00

Old rags:	Cents per lb.
Unassorted	About 0.75
No. 1 whites	4.40 to 4.70
No. 2 whites	3.60 to 3.80
Thirds and blues	2.80 to 3.00
Straight garments	1.80 to 2.00
Hard-back carpets	1.60 to 1.90
Soft-back carpets	2.30 to 2.60

Old rubber:	Cents per lb.
Boots and shoes	8.75 to 9
Trimmed arctics	6.75 to 7
Auto tires	4.5
Bicycle tires	4 to 4.5
Solid tires	5.25
No 1 inner tubes	24
Mixed white scrap	8 to 8.5
Mixed red scrap	6.5 to 7
Mixed black scrap	3.25
Garden hose	1.25 to 1.5
Cotton fire hose	2

The current prices of some waste materials in Chicago, as of August, 1919, were as follows:

	Per net ton
Scrap iron:	
No. 1 cast	$22
Stove plate	20
Malleable	18

	Cents per lb.
Old metals:	
Heavy wire, copper clips and heavy copper	18
Red brass	17
Red borings	15
Yellow brass	11
Yellow borings	11
Lead pipe	5
Tea lead	3
Tin pipe	55
Tin foil	35 to 40
Pewter	42
Zinc	5
Mixed rags, car load lots	4
Scrap rubber:	
Boots and shoes	7
Auto and bicycle tires	3
Tubes (mixed)	10

The selling prices of rubbish materials in the Chicago market, from quotations dated November 7, 1919, were as follows:

Copper	$0.16 per lb.
Light copper	0.15 "
Brass, red	0.16 "
Brass, heavy yellow	0.10½ "
Brass, lighter yellow	0.09 "
Brass, yellow borings	0.09 "
Brass, red	0.14 "
Lead	0.05¼ "
Zinc	0.05 "
Mixed iron	12.00 per ton
Mixed rags	$0.03 per lb.
Bagging	0.02 "
Newspapers	0.70 per 100 lb.
Mixed paper	0.60 "
Auto tires	0.03 per lb.
Auto tubes	0.09 "
Mixed boots and shoes	0.04 "
Arctic shoes (cloth covered)	0.04 "

C. RESULTS IN PRACTICE

As the practice of sorting in specially built plants has been fairly well developed in some of our cities, we describe a few of them below.

1. New York City.—The first rubbish sorting plant in the United States was built by Col. Waring, for New York City, on an experimental basis, and was operated from January 1, 1898, to August 11, 1900, and then abandoned. The rubbish was collected separately from a population estimated to be about 116,000, within the territory bounded by Sixth and Seventh Streets on the south, the Bowery and Fifth Avenue on the west, Twenty-second Street on the north, and the East River on the east. The area contained a number of large department stores. The plant was built by the City and operated by a contractor, with the results shown in Table 87. The quantity of rubbish delivered ranged from 40 to 50 loads a day.

TABLE 87.—RESULTS OF OPERATION OF EXPERIMENTAL RUBBISH SORTING PLANT, NEW YORK CITY

Year	Quantity of Rubbish		Payments to City by Contractor	
	Total, in tons	Pounds per capita per year	Totals	Per ton
1898	6710	116	$4141.00	$0.017
1899	5660	98	3109.00	0.549
1900 (7 months)	3300	98	3680.00	1.10

Of the total quantity of rubbish, it was found that 37% was sorted and sold, about 60% of the remainder was burned up, yielding 40% as ash. The material sorted out had the following composition, by weight:

Material	Percentage by weight
Paper, six grades	74.5
Rags, clothing, bagging, and twine	12.2
Carpets, four grades	3.3
Bottles, common and proprietory	2.5
Metals: Iron, brass, lead, and zinc	2.1
Tins	1.4
Leather: Shoes and scrap	1.9
Rubber: Shoes, hose, and mats	0.2
Whole barrels	1.4
Miscellaneous	0.5
Total	100.0

In 1902 another sorting plant, with incinerator, was built at Forty-seventh Street and the Hudson River. It had a capacity of about 50 tons per twenty-four hours, and cost $20,000, exclusive of the pier on which it was built. It consisted of a conveyor which passed through two rows of storage bins (Fig. 77) and discharged into the top-fed hopper of the furnace (Fig. 78). The materials were sorted into the bins, and the papers baled in hand-presses. A test of the plant was made on October 7, 1904, and Table 88 is a record of the materials sorted out. The quantity picked out was 48.8% of the total by weight, and 63.5% by volume. The duration of the weighing and measuring test was 4.5 hours.

FIG. 77.—Conveyor, and Men Sorting out Material, New York.
(From "The Disposal of Municipal Waste," by H. de B. Parsons).

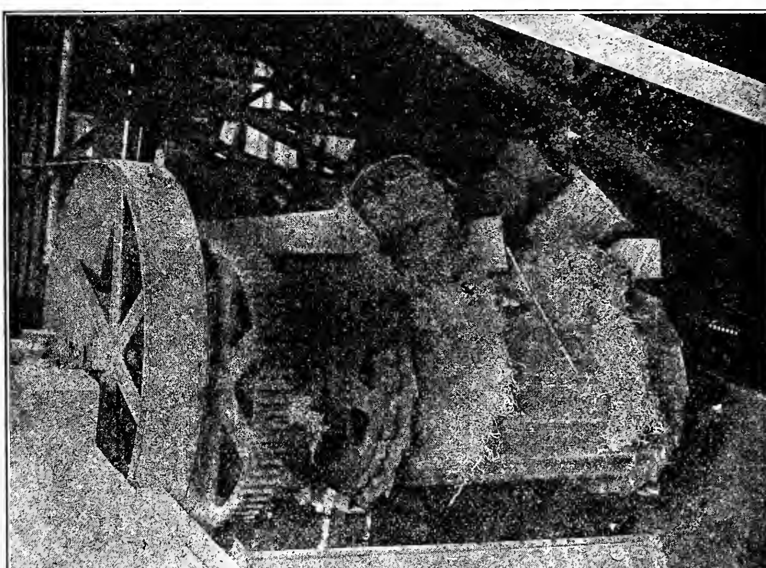


FIG. 78.—Conveyor Discharging into Furnace, New York.
(From "The Disposal of Municipal Waste," by H. de B. Parsons.)

A third rubbish sorting plant, with incinerator, was built in 1905 in Delancey Street, under the west approach of the Williamsburg Bridge. The plant comprised a rubbish sorting equipment, two furnaces for burning the residual rubbish, two 200-h.p. boilers, and an electric power plant, containing one 50-h.p. and two 100-h.p. units. The cost of the rubbish sorting and incinerating plant was $34,139, and of the electric power plant $49,391.

TABLE 88.—RECORD OF QUANTITIES OF RUBBISH SORTED AT 47TH STREET PLANT, NEW YORK CITY, OCTOBER 7, 1904

Material sorted	Cubic yards	Pounds
Newspapers	98.0	5,184
Manila paper	54.5	1,250
Pasteboard	105.0	4,909
Mixed paper	53.0	2,613
Mixed paper and rags	6.0	625
Books	0.5	259
Iron and tins	16.0	1,942
Bottles	0.5	363
Rags	6.5	1,007
Bagging	1.0	184
Carpets	1.5	274
Shoes	0.5	180
Hats	0.5	17
Rope	0.5	111
Barrels	21.0	2,826
Boxes	11.0	1,400
Totals	376.0	23,144

Two tests, made in December, 1905, lasting 5.5 hours each, gave the results shown in Table 89.

The plant actually handled about 1050 cu. yd. of rubbish a day, amounting to about one-fifth of the total daily output of the Boroughs of Manhattan and The Bronx.

A fourth rubbish sorting plant in the metropolitan area has been operated in East New York, a section of Brooklyn, by the American Railway Traffic Company, under a contract with Brooklyn. The plant is operated in connection with an ash dump. The building is 100 by 75 ft. in plan, is two stories high, and is of wood covered with corrugated iron. A part of the upper floor is used for unloading ash wagons into bins which discharge into trolley cars. Another part contains a short belt conveyor for rubbish sorting, and still another

contains the storage bins. The plant also has an incinerator. The ashes are run out by trolley to low land and used for filling.

Of these four New York plants, only the East New York station was in operation in 1915.

TABLE 89.—RESULTS OF TWO SORTING TESTS AT DELANCEY STREET PLANT, NEW YORK CITY

Items	Quantities Sorted	
	First test	Second test
Condition of rubbish	Dry	Wet
Total weight of rubbish, in pounds	31,193	21,175
Rubbish sorted out for sale, in pounds:		
Paper	6,876	6,435
Rags	1,800	610
Cans	250	200
Percentage of rubbish sorted out, by weight	28.6	34.2

In addition to the sorting plants, New York City has for many years sold the privilege of picking over the garbage and rubbish, at the dumps and scow transfer stations along the water front, for which contractors have paid approximately $1920 per week. The estimated quantity was 1800 tons per week, from which about 35% was picked out and sold. The value of the rubbish to the city was thus about $1.06 per ton.

2. Buffalo, N. Y.—A rubbish-sorting plant was built by the Buffalo Sanitary Company in 1905, and was purchased by the City in 1907. The building is of brick, 200 ft. long, 50 ft. wide, and 25 ft. high to the eaves, with a gable roof and monitor. It is divided into three compartments, containing, respectively, the rubbish-sorting plant, the incinerator, and the sewage pumps. The plant handles an average of 50 tons per day, and cost the city $65,000, exclusive of the sewage pumping machinery, but including one of the incinerators.

The rubbish-sorting plant occupies half the building, namely, an area 100 ft. by 50 ft., in which there is room for handling about 500 cu. yd. of rubbish per day. The delivery is made in large wagons, holding from 10 to 15 cu. yd., each wagon being fitted with a removable false bottom of wire screen. The wagons pass in at one end of the building on the ground floor through a large portal. The rubbish is dumped on the floor by lifting the false bottom with an overhead traveling pulley. Two laborers rake the rubbish on the belt conveyor, which begins on the first-floor level and rises at an angle of about 25°

through the sorting room to above the furnace, carrying the rubbish with it in a thin layer.

The length of the sorting platform is about 60 ft. On each side of the conveyor are ten pickers, each one sorting out a special article and depositing it in a bottom-dumping hopper, eight of which are set in a row on each side of the conveyor. Below some of the hoppers are the baling presses, hydraulically operated, in which the various kinds of papers and rags are baled ready for shipment.

In a small room below the sorting floor are the machines for disrupting tin cans, rolling them out into sheets, and punching out roofing washers. All bottles are sorted and sold as either mixed, sorted, or as broken glass.

After the conveyor passes through the sorting room, it discharges the waste rubbish on the floor above the furnace. There are two 40-ton incinerators, each having three grates, a combustion chamber, boiler, air heater, and forced-draft apparatus. One of the furnaces also burns some garbage. The steam generated is used to operate and light the plant, and to operate the sewage pumps. A coal-fired, 75-h.p. boiler is used as an auxiliary. In the annual financial summaries, the plant is credited with generating steam at a cost of 70 cents per hour. The operating results, from May 20, 1907, to June 30, 1917, inclusive, are shown in Table 90. One year's record of the materials sorted out is given in Table 91.

Table 90.—Annual Costs of Buffalo Rubbish Sorting Plant, Exclusive of Fixed Charges

Year ending June 30th	Annual costs	Revenue			Balance [1]
		Sale of recovered material	Sale of steam	Total return	
1908 [2]	$29,136.15	$32,307.99	$3,552.85	$35,860.84	$6,724.69
1909	28,985.58	28,635.58	2,629.73	31,265.31	2,279.73
1910	32,924.60	36,373.34	2,802.63	39,175.97	6,251.37
1911	38,622.43	37,162.43	3,908.62	41,071.05	2,448.62
1912	33,516.19	32,350.61	4,074.88	36,425.49	2,909.30
1913	36,683.92	41,358.29	4,565.58	45,923.87	9,239.95
1914	48,204.76	55,494.24	4,480.88	59,975.12	11,770.36
1915	51,890.72	55,356.14	4,467.40	59,823.54	7,932.82
1916	61,013.21	55,117.09	4,235.18	59,352.27	−1,660.94
1917	52,430.46	56,917.91	3,874.15	60,792.06	8,361.60

[1] If the fixed charges are deducted from the balance for each year, there would be, in general, a loss.

[2] Plant in operation from May 20, 1907, to June 30, 1908.

TABLE 91.—MATERIALS RECOVERED FROM REFUSE IN BUFFALO, N. Y., FROM JULY 1, 1917, TO JUNE 30, 1918

(From Report of the Refuse Utilization Plant, Buffalo)

SALES

6,730	bales newspapers	2,939,231 lb.	$10,287.38
15,987	bales mixed papers	6,785,680 "	20,357.28
1,803	bales manila paper	811,682 "	4,464.27
201	bags rags	103,800 "	1,927.62
5	bags flour bags	2,015 "	30.23
5	bags of charcoal bags	1,490 "	22.35
74	cars of tins	1,290,078 "	4,059.61
	Broken glass	204,440 "	630.44
275,077	mixed bottles		1,836.50
144,846	beer bottles		1,189.83
138	crates, beer, wood		13.15
38	crates, beer, iron		7.15
712.57	tons garbage destroyed. (Estimated at $1.00 per ton)		712.57
——	bales, old shoes	63,963 lb.	267.46
	Old metalware	13,440 "	31.50
	Old graniteware	13,980 "	32.77
	Old scrap iron	15,885 "	122.23
8,000	old electric bulbs		32.00
	Wood ashes	24,840 lb.	62.10
30	jugs		0.60
	Fire loss		1,670.00
	Pay-roll refund		2.75
			$47,759.79
	Steam furnished to Hamburg Pumping Station, 4,115½ hours at $2.08		8,560.24
			$56,320.03

CHARGES

Pay-roll	$48,689.58	
Maintenance and repairs	5,711.78	
Interest	1,440.00	
		$55,841.36
Net revenue		$478.67

Although Table 91 shows an apparent net revenue of $478.67 for the fiscal year, 1917–1918, there are certain charges, not included, which indicate that the works were actually run at a loss. For instance, Mr. George H. Norton, City Engineer, states that the salary of the superintendent, about $1800, is not included in the costs, but that one-third of his time should be charged against the sewage

pumping station. He also states that the cost of hauling cinders from the plant (about $2000 per year) is not included, and that no charge for overhead or plant depreciation is shown, excepting interest on outstanding bonds and insurance. He says, however, that the costs of maintenance and repairs have actually included much of real betterment to the plant.

3. Rochester, N. Y.—A combined rubbish sorting and incinerator plant was built in Rochester in 1912 by the Decarie Incinerator Company. The plant has a capacity of 60 tons per twenty-four hours, and cost approximately $100,000. The cost for the year 1913, exclusive of fixed charges, is given below:

Tons of refuse sorted	4,500
Cost of operation	$23,000.00
Revenue from salable refuse	15,000.00
Net loss of operation	8,000.00
Loss per ton sorted	1.77

The arrangement is similar to that of the Buffalo plant. The wagons drive into the building and dump into receiving hoppers which have sides sloping down toward a conveyor at the center. The conveyor rises to the sorting floor, where the salable articles are sorted out into bins, the remainder being delivered by the conveyor into the charging hoppers of two furnaces. Below the storage bins are the baling presses, driven by electric motors.

During 1913, 4500 tons of rubbish were handled. The operating force consisted of two engineers, five firemen, and from sixteen to twenty sorters. The sorters were paid 25 cents per hour, and the engineers $100 per month. The furnaces were operated continuously during the winter, but only during daytime in summer.

4. Miscellaneous.—In Washington, D. C., rubbish is disposed of partly by sorting and selling, and partly by burning. The work is done by contract.

Columbus, Ohio, has recently erected a municipal rubbish sorting and incinerating plant, from which the revenue for 1917 and 1918 was as follows:

	1917	1918
Bottles	$ 365.21	$ 116.33
Paper	1859.06	1876.06
Iron	145.53	58.19
Rags	579.94	239.45
Cans	452.59	1600.31
Metal	114.39	5.50
Miscellaneous	5.03	28.26
Totals	$3521.75	$3924.10

Boston and Pittsburgh also have sorting plants.

The U. S. Government, in the operation of the cantonments built during the late war, paid considerable attention to the utilization of camp refuse. The construction of incinerators for the temporary camps would have been both slow and expensive. It was therefore decided to keep the different kinds of refuse separated, i.e., to sort them, and dispose of each as found best under the local conditions.* "Much confusion existed during the early days of the war," which was reflected in the first contracts awarded for refuse disposal, and many complaints of wastefulness were made to the Food Administration. Later, contracts were accordingly arranged on the conservancy program of the Quartermaster's Corps "to bring about reduction in mess waste." "Prior to July 1, 1918, the average mess waste for all camps in the United States was nearly 2 lb. per man per day. This is far in excess of the wastes reported from municipalities, and even exceeds the wastage per person of first-class hotels." "After the above date, when new contracts took effect, the wastage was reduced to about $\frac{3}{4}$ lb. per man per day." This was brought about by "better discipline, definite regulations, better administration of the messes through educational literature, and primarily through the training of officers, cooks, and bakers in the army schools." The sorting that was decided on by the Quartermaster's Corps was a separation into four parts: 1, bread, to conserve wheat; 2, bones; 3, meat, fats, etc., for glycerine production if necessary; and 4, other garbage. Before a specific utilization as contemplated should be effected, the garbage was to be fed to hogs.

In Europe the principal plants have been in London, Bradford, Amsterdam, Munich, Vienna, and Buda Pest. Toward the end of the War Birmingham started a sorting plant (Chapter III).

The most developed case of sorting refuse in Europe is at Puchheim, a suburb of Munich, where the refuse from a population of more than 600,000 is picked over and finally disposed of. First, the finer materials and dust are sifted out on a moving and vibrating belt, and the bulky salable articles are picked out. In the adjoining room about 40 women stand on each side of the belt, each one picking out a designated material and throwing it into a designated wire basket. The substances thus removed are chiefly: Paper, white and green glass, rags, leather, bones, tinned cans, iron, brass, copper, tin, etc. The bones are treated with benzine, and, on the premises, are converted into grease, glue, bone meal, or charcoal. Garbage is cleaned, sterilized, and fed to hogs in an adjoining building. Paper is freed from dust, pressed into bales, and utilized for the manufacture

* *Municipal Journal and Public Works*, April 26 and May 3, 1919.

of pasteboard. Wood is burned under the boilers. Bottles are cleaned, disinfected, and sold. Tinned cans are sold as iron. No one enters the works until after donning working clothes, nor leaves them until after a good wash or bath. The working rooms are washed twice a day with dilute carbolic acid. It is reported by De Fodor that this very effective sorting contains the germ of faulty economics, in the fact that the total revenue hardly covers three-quarters of the necessary expenditure.

The data for Amsterdam for 1905 are: Population, 650,000; refuse per annum, 240,000 cu. m., weighing 100,000,000 kg., as follows:

	Kilograms
Sheet iron	310,000
Tinned plate	231,750
Tin and white metal	820
Zinc	15,010
Copper	19,050
Lead	380
Enameled iron	51,630
Cast iron	96,540
Green glass	106,750
White glass	80,000
Black glass	192,900
Bones	62,950
Leather	95,540
Rags	563,320
Paper	1,996,800
Total quantity picked out	3,823,440 kg.

D. SANITARY FEATURES

Rubbish sorting is unfavorably criticized because it requires the handling of miscellaneous, dirty—and possibly infected—materials from hospitals and sick rooms; and because the picked out materials are returned to circulation and use without much cleansing.

It should be remembered that it is impracticable to remove waste materials without manual contact. Therefore such material, when suspected of being dangerous or infectious, should be condemned by the Health Department and sterilized or burned at once on the premises or in incinerators, and should not pass over the picking platforms. The processes by which the rubbish is manufactured into articles for the market, frequently, but not always, sterilize it.

The effect of sorting on the operators at the plant is commented on by George H. Norton, Deputy Engineer Commissioner at Buffalo, as follows:

"This (the sorting) is done without nuisance and without material complaints of injurious effects upon the health of those engaged in this work. The subject of effect upon health may well be the subject of further detailed investigation."

Comment, by the Ohio State Board of Health, in "Health Hazards in Junk Sorting," is as follows:

"Our investigations covered 25 establishments (exclusive of paper manufacturers) located in five cities, employing wage-earners divided as follows:

Process	Number of establishments	Males	Females	Total
Paper and rag sorting.....	20	203	71	274
Refining metals..........	4	33	..	33
Waste, manufacturing.....	1	158	10	168
	25	394	81	475

"The exposure to dust was a bad hazard in 17 places, its source being the rags, paper, and metals handled. Quarters were very dirty and disordered in 19 places, while a fourth of the places were practically unprotected from the weather. The light was very poor where the workers were engaged in 8 places. Confined quarters giving poor opportunity for ventilation constituted a bad hazard in 13 places, and fairly so in 3 more. Heat was a bad hazard in one place employing 3 men. Chilling from winter cold was a hazard to the workers in at least one-half of the places. In one place, employing 17 men and women, the only heat was from unhooded salamanders, the gas from which filled the quarters. Fatigue was a considerable hazard in at least 3 places employing girls, due to the absence of seats, piece work, faulty postures, and the like.

"The general appearance of workers was fair to good in 10 of the plants (none, however, engaged in handling metals). The workers, as a rule, were very reticent about making complaints, but the ill effects of dust, unsanitary quarters, and long hours, were complained of by them. Our investigators discovered 4 cases of lead poisoning in 2 melting plants, 2 cases of tuberculosis, and reported that several cases of lockjaw had come from one of the large plants."

There have been no specific and serious complaints against rubbish sorting on health grounds, in New York City or elsewhere, so far as the authors have been able to ascertain. In 1916 the foregoing suggestion of Mr. Norton summed up the situation fairly well. It might be well, however, to add the caution, that, wherever sorting is found profitable, although rubbish from sick rooms may be collected separately and burned, it would be advisable to disinfect all rubbish before it is picked over or sorted, and before it leaves the works.

E. SUMMARY AND CONCLUSIONS

The recovery of waste materials is justified only when the operation is entirely sanitary, and when, after previous disinfection, it shows a sufficient margin of profit. It is certainly not advisable to sort rubbish at a net financial loss, in preference to other and simpler methods of disposal. Present available cost records indicate that the earnings from the sale of sorted rubbish, when including fixed charges, generally exceed only slightly the cost of operation. A small favorable balance is sometimes secured, also, by burning all the rubbish, if some use can be made of the resulting steam power. Considering both financial and sanitary aspects, it becomes questionable whether sorting is often advisable. Only a study of each local condition can determine the correct cost and the relative sanitary values of sorting and burning. In all cases, picking over and sorting rubbish should be done only by persons regularly licensed by the city or town, so as to control the work and, as much as possible, prevent unsanitary results.

A net financial profit from sorting rubbish must be balanced and justified to some extent by the kind of labor necessary to yield this profit. Unless the sacrifice due to such disagreeable conditions fully justifies the establishment of sorting stations for securing the small revenue, a progressive and well-to-do community should not engage in this business. The rag-picking contingent, chiefly in southern Europe, is a remnant of the Middle Ages, made up from the lowest classes, having low intelligence and morals, and a high death rate. The small profit and unpleasant occupation discourage a rising to higher levels in community life.

Exception, however, can be justly made here and there of separate ash dumps where much unburned coal can be picked out, and also of some rubbish dumps, where inoffensive materials may be gathered by licensed pickers without much objection.

In Europe sorting of mixed refuse is not generally favored, for sanitary reasons, and in many cities its abandonment has been recommended. De Fodor, the Hungarian author of an able work on "Electricity from Refuse" (1911), says:

> "In our century and in the name of hygiene and humanity, there should no longer be people, who, to earn their living, are compelled by a municipality to pick over its refuse."

Dr. Thiesing, of the Berlin Experiment Station, says, on the other hand, that each city should decide the question on its own basis, but that in every case all picked-over material should be disinfected before it leaves the works.

CHAPTER X

INCINERATION OF REFUSE

The disposal of refuse by incineration or burning is practiced extensively, and in several ways. It has been used for almost all kinds of refuse, either separately or combined. The earliest and simplest methods are the burning of garbage in kitchen stoves or house furnaces, and the burning of rubbish on a pile in the back yard. Manure has sometimes been burned under steam boilers.

Municipal refuse incineration, sometimes called destruction or cremation, in specially designed furnaces, originated in England, where it was introduced successfully for the incineration of mixed refuse, in 1874 at Nottingham, by Alfred Fryer, a contractor. Two years later, a somewhat improved refuse furnace was built by him at Manchester. It consisted of a series of cells charged through hoppers at the top and fitted with grates sloping toward the front. These early plants were sufficiently successful to cause a further development of this method of disposal, so that now it is practically the only one used on a large scale in England.

On the continent, the nature of the refuse and the conditions of labor and population were sufficiently similar to those in England, so in time the incineration of mixed refuse came into use also in France and Germany, and very much along the lines followed in England. The development there, however, has not been so extensive as in Great Britain, where there are now more than 200 plants. The first large one in Germany, designed by F. Andreas Meyer, City Engineer, was built at Hamburg in 1896. It was patterned chiefly after the English Horsfall furnace, but forced draft by fans with pre-heated air was preferred to the steam jet advocated by Horsfall. Since this first plant was built, German engineers have developed new designs, holding to the English original in principle, but changing the arrangement of the grates, the method of feeding, and other details.

The evolution of incineration in America has been somewhat along other lines, due to different local conditions, especially the character of the refuse. In American cities the population has spread more thinly over larger areas, increasing the hauls and affording more

opportunity than in Europe for the disposal of ashes and rubbish by dumping. Disposal of garbage by dumping, however, caused nuisances, so that a method of disposal of this material alone—the refuse which most quickly produces a nuisance—became desirable.

The early furnaces in America, therefore, were intended largely for the burning of garbage; those in Europe had been designed to burn mixed refuse. The former practice requires the addition of fuel, such as coal, oil, or gas. The latter practice, because mixed refuse contains sufficient combustible to burn of itself at a high temperature, does not need additional fuel.

American furnaces also required less labor than those of the English type, but the cost of fuel increased the total expense. In the operation, therefore, there was always a temptation to lower the cost by reducing the quantity of fuel added. The temperature of combustion was thereby lowered, and nuisances frequently resulted. The hot gases of combustion from English furnaces have been used successfully for steam raising and power production. There is thus introduced an economic reason for the maintenance of high temperature, which is also necessary for the complete destruction of organic matter. The two kinds of furnaces have been spoken of, therefore, as the "high-temperature" and "low-temperature" types.

The first garbage furnace in the United States was designed by Lieut. H. J. Reilly for the United States Government, and was erected on Governors Island, New York Harbor, in 1885. The first municipal plant was built during the same year in Allegheny City, Pa., by the Rider Company. Both plants were designed to burn garbage with coal. The first furnace type that came into extensive use was built in Des Moines, Ia., in 1887, by Andrew Engle. It had a large horizontal grate on which the garbage was thrown from above to be first dried, then partly burned by a coal or oil fire kept going at one end, and finally completely burned, together with the fumes, at the other end of the furnace, just before the gases went up the chimney.

In 1893, in Ellwood, Ind., Sam. W. Dixon built a furnace which was also extensively used. It had a large horizontal grate (on which the garbage was thrown) which divided the furnace into an upper main destructor chamber and a lower evaporation chamber. A double fire-box was placed at one end, from which the heat generated by coal fires could pass, either into and through the upper or the lower chamber, to the other end into a combustion chamber for deodorizing and destroying the products of combustion. A later pattern included a third compartment or drying chamber over the main chamber, on which the garbage was first placed to be dried and then thrown into the middle chamber for incineration.

In 1901 Minneapolis built the first plant of quite a number designed by F. L. Decarie. The furnace receives the garbage in a crate of steel pipes suspended over the fire, to effect the preliminary drying and prevent a packing of the mass. In order to make the steel pipes more durable, water was circulated through them. Instead of fire-brick sides, water jackets of steel were used, with the disadvantage of keeping the furnace temperature low and preventing the required high-temperature combustion.

In 1903 a small experimental rubbish burning plant was built in New York City. It was found that 1 lb. of rubbish produced 1.4 to 1.5 lb. of steam.* Thereupon the rubbish burning plants at West 47th Street and Delancey Street were built in 1906.

Four Dixon furnaces were built in Queens Borough, New York, in 1906. They burned in one year 5600 tons of garbage and 680 tons of rubbish. It was necessary, however, to add 766 tons of coal. One ton of coal was required to burn up 7.3 tons of garbage.

Since the introduction of the first garbage furnaces, their use and development in America has been rapid, so that, at the present time, we have more than 200 municipal plants in operation. They are all similar in principle, consisting of a hearth on which the wet garbage falls from the charging holes at the top of the furnace. At one end of this hearth, in the earlier designs, is a coal grate, the hot gases from which pass over—and in the Dixon furnace also under—the garbage hearth on their way to the chimney. In this way the garbage is first dried, and then is stoked down on the hearth and burned. Occasionally, an additional coal grate is set near the chimney, as first recommended in 1890 by Col. Jones, of Wrexham, England, and called by him a "crematory," so that any unconsumed gases may be completely burned before escaping into the air. The larger plants consisted of a series of garbage hearths and coal grates, and natural draft with cold air was used.

Many of these garbage furnaces have failed to operate satisfactorily, partly due to improper design and construction of details, and partly to unskilled operation and a tendency to use too little fuel. Later designs, including those by S. R. Lewis, have included mechanical stoking and better construction, so that more satisfactory operation has resulted. The American garbage furnace costs less to build than the English type for mixed refuse, and has been useful in many smaller cities, where suitable plant locations were available, where occasional incomplete combustion was not objectionable, and where the furnace was not utilized to generate power.

During the last dozen years, successful adjustments of the furnaces

* Parsons, "Disposal of Municipal Refuse," pp. 122 and 123.

of English type to American conditions have been introduced. The first successful plant was built at Westmount, a suburb of Montreal, Que., in 1906. Its capacity was 50 tons of mixed refuse per twenty-four hours. This first plant was followed by smaller ones at Vancouver, Seattle, and West New Brighton, and, in 1910, a very large plant was built at Milwaukee, with a capacity of 300 tons of mixed refuse per twenty-four hours.

These plants were all hand-charged; but, since 1910, mechanical charging apparatus have been developed, and plants with this improvement have been put into successful operation, for instance, at Clifton, Paterson, Savannah, Atlanta, and Toronto. All these plants are equipped with boilers for steam raising, and can develop useful power in excess of that required for plant operation. At Milwaukee the steam is used to generate electric power for operating screw pumps to pump water from Lake Michigan into the Milwaukee River, a mile above its mouth, and thereby to flush it. At Westmount the steam is used for generating electricity for street lighting. At Savannah the steam is used for pumping part of the city's water supply.

There are now in use, therefore, two types of incinerators: The English furnace for burning mixed refuse without additional fuel, and the American garbage furnace, designed to operate with additional fuel. The first of these types we shall call " Refuse Incinerators " and the second " Garbage Furnaces."

Refuse incinerators are either hand-charged or mechanically-charged, depending on the method of delivering the refuse into the furnace. They are top-fed, front-fed, or back-fed depending on the location of the charging door. Garbage furnaces are also either hand-charged or mechanically-charged, but are almost always of the top-fed type. Mechanical charging has been developed chiefly in America.

A. FUNDAMENTAL CONSIDERATIONS

Combustion or incineration is the process of combining certain elements in fuels with atmospheric oxygen to produce heat and therewith to destroy the organic matter of the refuse. A furnace is required for this process. As a temperature of at least 1250° Fahr. is also desired, and, as the thermal efficiency of furnaces for refuse cannot be as high as when coal is used, a careful design and operation, based on correct principles of combustion, are necessary to maintain the incineration at the foregoing temperature.

The incinerating or calorific value of refuse depends chiefly on its composition. For this reason it is essential to know the proportions of its combustible matter. It has been assumed, as a minimum figure,

that $\frac{3}{4}$ lb. of refuse should produce 1 lb. of steam (Milwaukee); yet this efficiency has not always been attained. On the other hand the best incinerators have produced $2\frac{1}{2}$ lb. of steam—and more—from 1 lb. of refuse. Where steam production has been most efficiently developed, unfortunately, we find the fewest records of a proper analysis of the refuse to verify the degree of efficiency. To prevent undesirable results at the outset, or a shortening of the life of the plant, it is desirable to ascertain, before the designs are made, the approximate composition of the refuse and its calorific value.

The principal elements required in combustion are carbon, hydrogen, and oxygen. Carbon combines with oxygen to form CO and CO_2. It will burn to CO_2 when in the solid state, or partly in the solid and partly in the gaseous state, the change being first from C to CO and then from CO to CO_2. When the supply of air to the fire is insufficient, CO, or carbon monoxide, is not further oxidized, but remains as such.

Free hydrogen combines with oxygen to form water, with the production of intense heat. Hydrogen in this state has a calorific value of 62,000 B.t.u. per pound, but the hydrogen present in refuse as water does not add heat to the combustion. The heat required to split up the hydrogen and oxygen in the water is greater than the heat developed in the recombination of the two elements, by an amount of about 10,000 B.t.u. per pound.

Carbon and hydrogen also appear in refuse as hydrocarbons, such as tar and pitch. Kent * states that:

> "If the hydrocarbons, on their first issuing from amongst the burning carbon are mixed with a large quantity of hot air, these inflammable gases are completely burned with a transparent blue flame, producing carbon dioxide [CO_2] and steam. When mixed with cold air they are apt to be chilled and pass off unburned."

Carbon and free hydrogen do not often constitute by weight more than one-fifth of the mixed refuse. They are, therefore, masked by a large quantity of inert material and water, and it is difficult to bring the oxygen of the draft air into intimate contact with the combustible substances.

The total heat of the combustion of these substances with oxygen may be determined with a Mahler's bomb, as described in Chapter I. The total heat of combustion of 1 lb. of fuel, or the calorific value, in British thermal units per pound, may be determined from the following expression:

$$H = 14500\left[C + 4.28\left(H - \frac{O}{8}\right)\right]$$

* "Mechanical Engineers' Pocket-Book," 9th Ed., p. 816.

in which the carbon, hydrogen, and oxygen are expressed in decimals of a pound per pound of refuse. Thus, a refuse containing 20% of carbon, 3% of hydrogen, and 6% of oxygen would have a calorific value of 4296 B.t.u. Some calorific values of refuse, as determined by tests, are given in Chapter I.

The quantity of air required to burn refuse must be calculated in order to determine the necessary draft and the proper sectional areas of flues and chimneys. If the composition of the refuse is known, the calculation may be made in the following manner:

Assume, as before, that the refuse contains 20% of carbon, 3% of hydrogen, and 6% of oxygen. The atomic weight of carbon is 12 and of oxygen 16, so that 12 lb. of carbon require 32 lb. of oxygen to burn completely to CO_2. Each pound of carbon, therefore, requires 2.67 lb. of oxygen. Hydrogen has an atomic weight of 1. In burning to water, or H_2O, 2 lb. of hydrogen require 16 lb. of oxygen. Therefore, each pound of hydrogen requires 8.0 lb. of oxygen.

The theoretical quantity of oxygen required to burn 1 lb. of the refuse can be calculated as follows:

$$\begin{aligned} 2.67 \times 0.20 &= 0.534 \text{ lb. of O for the carbon,} \\ 8 \times \left(0.03 - \frac{0.06}{8}\right) &= \underline{0.180 \text{ lb.}} \text{ of O for the hydrogen,} \\ &\ 0.714 \text{ lb. of O for the refuse.} \end{aligned}$$

In the first line the second figure (0.20) is the quantity of carbon in 1 lb. of refuse. In the computation of the oxygen required to burn the hydrogen, an allowance must be made for the 6% of oxygen already in the refuse. Hence, in the second factor of the second line, the figure 0.03 (quantity of hydrogen in 1 lb. of refuse) is corrected by the equivalent, as hydrogen, of the quantity of oxygen present, or one-eighth of 0.06, as shown.

Air contains by weight 23% of oxygen, so that a refuse of the assumed composition would require, theoretically, approximately 3.1 lb. of air per pound of refuse. In usual practice, however, incinerators cannot be operated with the quantity of air theoretically required, and an excess must be supplied, amounting to from 50 to 100% of the computed quantity, or from 4.5 to 6.0 lb. of air per pound of mixed refuse. Areas of flues and openings for the hot gases must be computed with allowances for this excess and for the temperature of the gases at the points under consideration.

A velocity of air in the flues of not more than 20 ft. per second, and averaging about 10 ft. per second, is desirable. If the flues are too small, a back pressure of hot gases against the furnace fronts and

doors will result, so that exposed ironwork will be burned out. The flues in the refuse incinerator at Newcastle-upon-Tyne, in England, were too small, and the doors in the furnace fronts were burned out two or three times a year.

For convenience of calculation, the volume and weight of air at different temperatures are given in Table 92. The volume of 1 lb. of various gases at different temperatures is given in Table 93. The atomic weights, calorific values, and weights of oxygen required, per pound of combustible, are given for various substances in Table 94. Table 95 gives the approximate volume of the products of combustion at different temperatures for different quantities of air supply.

B. PLANT LOCATION

As already indicated, refuse incinerators and garbage furnaces have been built in a number of towns in close proximity to dwellings and other buildings, without prejudice to such property. The question of plant location is important, on account of its influence on the cost of collection. Expert engineering opinion, as set forth in a number of reports, maintains that high-temperature refuse incinerators or garbage furnaces can be placed nearer to centers of population than can any other plants for refuse disposal. Collection costs, therefore, as a rule, will be lower when the final disposal is by incineration.

Regarding the effect on the people residing in the vicinity, Goodrich says: "It is no exaggeration to say that the discharge from the modern destructor chimney is of a much less offensive nature than is the case with an average coal-fired boiler chimney."

The location of a few plants, partly under unfavorable conditions, but in successful operation, may be described as follows:

Milwaukee.—Refuse Incinerator.—Capacity, 300 tons per twenty-four hours. Plant is at entrance to harbor and within 1 mile of the business center of the city. Saloons and cheap frame houses are within half a block.

West New Brighton—Refuse Incinerator.—Capacity, 60 tons per twenty-four hours. Plant is on water front, about 50 ft. lower than Main Street, two blocks away. Main Street is lined with stores of a good class, flats, boarding houses, and second-class residences.

Atlanta.—Refuse Incinerator.—Capacity, 240 tons per twenty-four hours. Plant is in railroad yards, about three-quarters of a mile from the business center of the city.

Vancouver.—Refuse Incinerator.—Capacity 40 tons per day. Plant is on an alley, 200 ft. from a main street, about four blocks from the City Hall, and in a well built-up business district.

TABLE 92.—VOLUMES AND WEIGHTS OF DRY AIR AT ATMOSPHERIC PRESSURE, 14.6963 LB.

$$\text{Weight, in pounds per cubic foot} = 0.080728 \times \frac{491.6}{T+459.6}$$

$$\text{Volume, in cubic feet per pound} = \frac{T+459.6}{0.080728 \times 491.6}.$$

Temperature, in degrees, Fahrenheit	Volume, compared to volume at 32 degrees	Weight of one cubic foot of air, in pounds	Volume of one pound of air, in cubic feet	Temperature, in degrees, Fahrenheit	Volume, compared to volume at 32 degrees	Weight of one cubic foot of air, in pounds	Volume of one pound of air, in cubic feet
0	0.9349	0.08635	11.581	725	2.4108	0.03348	29.863
10	0.9552	0.08451	11.883	750	2.4617	0.03279	30.494
20	0.9756	0.08275	12.085	775	2.5126	0.03213	31.124
30	0.9959	0.08106	12.337	800	2.5635	0.03149	31.755
32	1.0000	0.08073	12.387	825	2.6144	0.03088	32.385
40	1.0163	0.07943	12.589	850	2.6653	0.03029	33.016
50	1.0366	0.07788	12.841	875	2.7162	0.02972	33.646
60	1.0570	0.07638	13.093	900	2.7671	0.02917	34.277
70	1.0774	0.07494	13.346	925	2.8180	0.02864	34.907
80	1.0977	0.07354	13.598	950	2.8689	0.02814	35.536
90	1.1181	0.07220	13.850	975	2.9198	0.02765	36.168
100	1.1384	0.07091	14.102	1000	2.9707	0.02718	36.799
110	1.1588	0.06967	14.354	1025	3.0216	0.02672	37.429
120	1.1791	0.06847	14.606	1050	3.0725	0.02628	38.060
130	1.1995	0.06730	14.858	1075	3.1234	0.02585	38.690
140	1.2199	0.06618	15.111	1100	3.1743	0.02543	39.321
150	1.2402	0.06509	15.363	1125	3.2252	0.02503	39.952
160	1.2606	0.06404	15.615	1150	3.2761	0.02463	40.582
170	1.2809	0.06302	15.867	1175	3.3270	0.02426	41.212
180	1.3013	0.06204	16.119	1200	3.3779	0.02390	41.843
190	1.3217	0.06108	16.372	1225	3.4288	0.02354	42.473
200	1.3420	0.06015	16.624	1250	3.4797	0.02320	43.104
210	1.3624	0.05924	16.876	1275	3.5306	0.02286	43.734
212	1.3664	0.05908	16.926	1300	3.5815	0.02254	44.365
220	1.3827	0.05838	17.128	1325	3.6323	0.02222	44.994
230	1.4031	0.05754	17.381	1350	3.6832	0.02192	45.625
240	1.4234	0.05671	17.663	1375	3.7341	0.02162	46.255
250	1.4438	0.05591	17.885	1400	3.7850	0.02133	46.886
260	1.4642	0.05513	18.137	1425	3.8359	0.02104	47.517
270	1.4845	0.05438	18.389	1450	3.8868	0.02077	48.147
280	1.5049	0.05364	18.641	1475	3.9377	0.02051	48.777
290	1.5252	0.05293	18.893	1500	3.9886	0.02024	49.408
300	1.5456	0.05223	19.145	1550	4.0904	0.01974	50.669
320	1.5863	0.05089	19.649	1600	4.1922	0.01926	51.930
340	1.6270	0.04962	20.154	1650	4.2940	0.01880	53.191
360	1.6677	0.04841	20.659	1700	4.3958	0.01836	54.452
380	1.7085	0.04725	21.164	1750	4.4876	0.01795	55.713
400	1.7492	0.04615	21.668	1800	4.5993	0.01755	56.973
420	1.7899	0.04510	22.172	1850	4.7011	0.01717	58.234
460	1.8713	0.04314	23.180	1900	4.8029	0.01681	59.495
480	1.9120	0.04222	23.685	2000	5.0065	0.01612	62.017
500	1.9528	0.04134	24.189	2100	5.2101	0.01549	64.539
520	1.9935	0.04050	24.694	2200	5.4137	0.01491	67.061
540	2.0342	0.03969	25.198	2300	5.6173	0.01437	69.583
560	2.0749	0.03891	25.702	2400	5.8208	0.01387	72.104
580	2.1156	0.03816	26.207	2500	6.0244	0.01340	74.626
600	2.1563	0.03744	26.711	2600	6.2280	0.01296	77.148
620	2.1971	0.03674	27.216	2700	6.4316	0.01255	79.670
640	2.2378	0.03607	27.720	2800	6.6352	0.01217	82.192
680	2.3192	0.03481	28.729	2900	6.8388	0.01180	84.714
700	2.3599	0.03421	29.233	3000	7.0424	0.01146	87.236

Table 93.—Volume of 1 Pound of Various Gases at Different Temperatures, Under a Pressure of 1 Atmosphere

(Volume in cubic feet)

Temperature, in degrees, Fahr.	Carbon dioxide, CO_2	Carbon monoxide, CO	Nitrogen, N	Steam, H_2O	Sulphur dioxide, SO_2	Air
100	9.22	14.53	14.52	.....	6.36	14.10
200	10.86	17.09	17.11	.....	7.50	16.62
300	12.51	19.65	19.69	30.53	8.63	19.15
400	14.15	22.21	22.28	34.95	9.77	21.67
500	15.79	24.77	24.87	39.37	10.90	24.19
600	17.44	27.33	27.46	43.79	12.04	26.71
700	19.08	29.89	30.05	48.21	13.17	29.23
800	20.73	32.45	32.64	52.63	14.31	31.76
900	22.37	35.01	35.23	57.05	15.44	34.28
1000	24.01	37.57	37.82	61.47	16.58	36.80
1100	25.66	40.13	40.41	65.89	17.71	39.32
1200	27.30	42.69	43.00	70.31	18.85	41.84
1300	28.95	45.25	45.58	74.73	19.98	44.37
1400	30.59	47.81	48.17	79.15	21.12	46.89
1500	32.23	50.37	50.76	83.57	22.25	49.41
2000	40.45	63.17	63.71	105.67	27.93	62.02
2500	48.67	75.97	76.66	127.77	33.60	74.63
3000	56.89	88.77	89.61	159.87	39.28	87.24

Table 94.—Some Combustion Data for Various Substances

Substance	Symbol	Atomic weight	Combustion product	Weight of oxygen per pound of substance, in pounds	Air Required per Pound of Substance		Calorific value, in British thermal units, per pound of substance
					Pounds	Cubic feet at 62° Fahr.	
Oxygen.........	O	16	......	......	.. .	.....	......
Hydrogen.......	H	1	H_2O	8.00	34.80	457	62,032
Carbon.........	C	12	CO	1.33	5.80	76	4,452
"	..	12	CO_2	2.67	11.60	152	14,500
Carbon monoxide	CO	28	CO_2	0.57	2.48	33	4,325
Marsh gas......	CH_4	16	CO_2 and H_2O	4.00	17.40	229	26,383
Olefiant gas.....	C_2H_4	28	CO_2 and H_2O	3.43	15.00	196	21,290
Sulphur........	S	32	SO_2	1.00	4.35	57	4,032

TABLE 95.—TEMPERATURE OF COMBUSTION AND VOLUME OF GASES WITH DIFFERENT QUANTITIES OF AIR SUPPLY

Temperature of gases, in degrees, Fahr.	Supply of Air, in Pounds, per Pound of Fuel				
	2 lb.	3 lb.	4 lb.	5 lb.	6 lb.
	Volume of Gases, in Cubic Feet, at Temperatures Indicated				
68	27	40	54	68	80
104	29	43	57	71	86
212	34	51	68	85	102
392	43	65	86	108	130
572	53	78	105	131	156
752	62	92	123	154	184
1112	80	120	159	199	240
1472	98	147	196	245	294
1832	116	174	232	280	348
2500	151	226	302	378	452

Oak Park.—Garbage Furnace.—Capacity, 30 tons per twenty-four hours. Plant is on a traveled street, about four blocks from the business center of the town.

Ft. Wayne.—Garbage Furnace.—Capacity, about 40 tons per twenty-four hours. Plant is on a traveled road, about ten blocks from the business center of the city.

Within the Metropolitan District of London a large number of incinerators operate without objection. Goodrich states that "no less than 94% of the refuse destructors [incinerators] working at present [1904] in Great Britain are in close proximity to houses." Limiting conditions of location can be determined from a study of plants critically situated, where operating conditions have been reasonably free from objectionable influences and are otherwise satisfactory.

A more serious feature of the location of incinerators is the necessary concentration of collection wagons in one vicinity. This concentration is an argument for having a number of smaller plants in different localities, instead of one large plant. The cost of collection is thus reduced by shorter hauls, but it costs more per cubic yard to incinerate in separated small plants than in a single large plant.

The collection wagons need not create a nuisance if they are of proper size, are covered, and carry fresh garbage. Incinerator buildings should be substantial and attractive, and surrounded by parked

grounds. The comparative costs of the buildings and equipment of a number of plants are given in Chapter XII.

C. DESIGN AND CONSTRUCTION

The design of a refuse incinerator may be divided into the following parts:

a. A furnace built of brick, heavily braced with structural steel, and containing one or more cast-iron or brick grates and ashpits. A combustion chamber is commonly included in the furnace.

b. An opening or special apparatus for charging refuse into the furnace.

c. The necessary ducts, valves, and blowers to deliver the requisite quantity of air into the furnace and bring the oxygen into contact with the combustible parts of the refuse.

d. The necessary flues and chimney to conduct the gases of combustion out of the furnace and into the atmosphere. In the best types of incinerators the hot gases are passed through air heaters to preheat the forced-draft air, and also to boilers for the generation of steam. A combustion chamber is included, to insure complete incineration of the volatile matter and to remove dust from the escaping gases.

e. An opening, with or without means for removing the residual clinkers and ashes from the grates and ashpit.

The design and arrangement of these essential parts of a refuse incinerator depend on the type of furnace desired, the refuse to be burned, the experience and preferences of the designer, and some local conditions. However, the principles of the design of furnaces are similar for all types. A diagrammatic section typical of one unit of the Milwaukee incinerator is shown in Fig. 79.

1. Furnace Proper.—An important difference in the design for various furnace types is caused by the character and condition of the refuse to be burned. For instance, a wet refuse, such as garbage, or mixed refuse containing a high percentage of garbage (70%), generally requires some kind of a drying hearth from which the refuse can be raked down on the grate. With dry refuse this is not necessary, because it can be charged directly on the grate.

The furnace structure of a mixed refuse incinerator ordinarily contains from two to six grates and a common combustion chamber. It is rectangular in plan and from 12 to 16 ft. wide, the length being determined by the number of grates. The height is from 12 to 18 ft. The walls are of face-brick, backed with common brick, and lined with fire-brick. On the outside of the brickwork there is a series of ver-

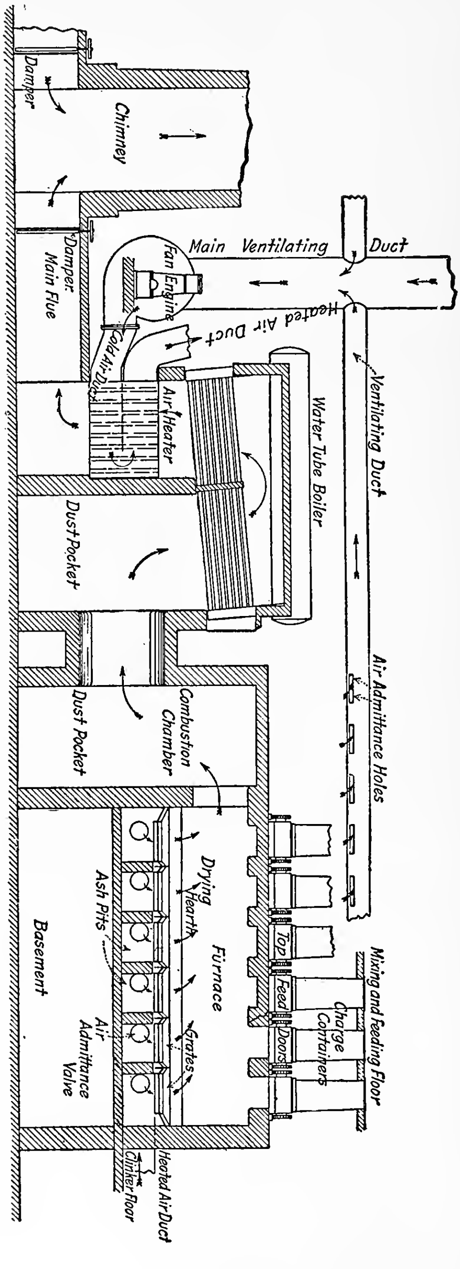


FIG. 79.—Diagrammatic Section Typical of One Unit of Milwaukee Refuse Incinerator, Showing Course of Air Supply and Gases of Combustion.

(This section does not fully represent the actual construction, but serves the purpose indicated by the title).

tical and horizontal channel-iron or I-beam back-stays, held at the top and bottom by heavy tie-rods. The cast-iron furnace fronts are usually attached to the vertical stays. The whole structure must rest on a substantial foundation.

In many of the early garbage furnaces, built in America, and by contractors under inadequate specifications, the bracing was not sufficient. This caused distortions which broke the fronts and cracked the brickwork, producing openings for the entrance of cold air. Low temperatures resulted, and complaints of the resulting nuisances caused many of these garbage furnaces to fall into disfavor and be abandoned.

The area of the grate depends on the character of the refuse and its rate of burning. The best size must be determined largely in practice. Table 96 shows the composition of refuse and rate of burning of mixed refuse per square foot of grate surface in a number of incinerators of different designs. With a fairly dry mixed refuse of high calorific value, the rate of burning per square foot can be increased materially by introducing a greater draft under a higher pressure, equal to from 6 to 10 in. of water, as is done at Hamburg, Germany.

The arrangement or setting of the grate in the furnace depends on the general design, and is partly controlled by the necessity for keeping the grate cool by contact with the forced draft. The air, if preheated, comes to the grate at a temperature of about 300° Fahr., which is not high enough to burn out the grate bars.

As ordinarily set, a fixed grate has an area of from 20 to 30 sq. ft. It is built up of bars, hooked or hinged at the back, and resting on a sliding face in front, in order to provide amply for expansion and contraction. The grate-bars may be built of cast-iron channels. They are perforated with numerous holes for a better distribution of the draft air to the burning refuse. The bars should have narrow spaces between them, often $\frac{3}{16}$ in., and several bars are usually cast together. In some furnaces the center grate-bar is ridged about 3 in. high, so as to form a weak section in the resulting clinker, which is therefore more easily broken and withdrawn. The sides of the grate are protected with a cast-iron curb, the depth of which depends on the nature of the refuse to be burned. A maximum curb depth of about 12 in. is used for a comparatively dry and light refuse. Such a refuse may be charged on the grate to a depth of about 3 ft.

The side-curbs and grate-bars are kept from burning out by the comparatively cool forced-draft air, which must reach all parts of the grate. In this matter valuable experience has been gained at the refuse incinerator at Atlanta, Ga. In the original design the hot clinker was dropped from a sliding grate into the ashpit below. The

TABLE 96.—COMPOSITION OF REFUSE AND RATE OF BURNING IN REFUSE INCINERATORS

City	Composition of Refuse, Percentage by Weight				Rate of burning Pounds of refuse per square foot, of grate area per hour	Notes
	Garbage	Ashes	Rubbish	Manure		
Milwaukee, Wis.	56.7	30.6	5.9	6.8	63.0	Official test of hand-charged plant
	29.7	59.7	6.8	3.8	65.0	
	40.8	41.0	4.8	13.4	64.0	
West New Brighton, N. Y.	46.6	38.5	14.9	....	52.0	Official test of hand-charged plant
	11.8	82.9	5.3	....	49.6	
Westmount, Que.	36.9	63.1	Included with garbage	....	40.2	
	51.0	49.0		....	62.7	
Seattle, Wash.	Mixed refuse		....	....	58.4	Two years operation. Hand charged
Clifton, N. Y.	Summer refuse		....	....	143.3	Official test of mechanically-charged and clinkered plant
	Winter refuse		....	....	139.0	
Atlanta, Ga.	48.5	16.6	34.9	....	129.0	Special test of mechanically-operated plant
Savannah, Ga.	45.0	10.0	40.0	5.0	80.6	Official test of mechanically-charged and clinkered plant
Halifax, N. S.	16.0	75.0	9.0	....	77.7	Official test of Sterling plant

forced-draft air was admitted through the bottom of the ashpit. It passed up through the hot clinker, absorbing heat on its way to the grate proper. When it reached the grate it was too hot to allow sufficient cooling, and, with a poor distribution of the material, the grates burned out. In the ashpit, the clinkers became so hot that they sometimes melted and the mass ran into the air inlets at the bottom. This condition was relieved successfully by introducing the forced-air draft through the sides of the ashpit, instead of at the bottom.

In some designs, the air is introduced through spaces just under the side-curbs; this gives it additional heat. It then passes to the ashpit and through the grate up to the fire.

The division of the furnace into a number of grates produces a more uniform average fire over them and a more uniform heat in the combustion chamber. The effect of a poor fire on one grate will be improved by good fires on the other grates. When one grate is being clinkered, the action of only one part of the furnace is reduced. With divided ashpits, also, each grate can be operated as an independent unit. Grouping the cells back to back, with the main flue between, reduces the loss by radiation and allows thorough mixing of the gases from the different cells.

Garbage furnaces must contain a drying hearth and a main grate, and are generally built with complete and separate cells or units, rather than with multiple cells. The requisite size of the furnace depends on the moisture contained in the garbage and the consequent rate of drying, rather than on the rate of burning on the grates. As ordinarily designed, garbage furnaces provide a sufficient area of drying hearth to handle one day's delivery of garbage, the whole quantity being stored within the furnace. An exception to this type is the mechanically-fed furnace designed by S. R. Lewis, in which storage is provided in a bin outside of the furnace, and the drying hearth is made large enough to dry small quantities of garbage, as they are intermittently charged into the furnace.

In the Lewis design the drying grate is sloped to the main grate at an angle of 45°, in order to provide drainage and facilitate stoking. When the drying grate is set horizontally or is slightly arched, drainage and stoking are facilitated by leaving holes in the hearth. Fire-brick hearths, when receiving wet garbage on top, absorb moisture and are subject to intense heat below. They will, therefore, warp and crack in from one to two years.

The principal material of construction in the furnace is fire-brick, and it should be selected carefully. Bricks in arches, when subjected to great heat, should have a high refractory quality, a comparatively

porous texture, and a minimum contraction and expansion under changes of temperature. In bricks for drying hearths which are to receive wet refuse, and also are subjected to high temperatures, the percentage of absorption of water must be low. They should be close-grained and dense. Fire-bricks around stoking doors, subject to abrasion from tools and also to great heat, must be hard and refractory. The Semet Solvay Company has found, after a large number of trials, that in coke ovens a 95% silica brick gives the best service under great abrasion and great heat. The fire-bricks used in the construction of the refuse incinerator at Milwaukee were selected carefully for the various parts of the furnace. Their composition and tests are shown in Table 97.

TABLE 97.—ANALYSES OF FIRE-BRICK USED IN MILWAUKEE REFUSE INCINERATOR

Percentages of chemicals by weight

Substance, absorption, and elongation	Kind of Brick		
	C. Franklin Crown	Royal Star	Scioto Star
Silica	53.25%	55.25%	56.17%
Aluminum	41.01	41.78	40.86
Iron oxide	3.36	1.67	1.53
Lime	0.41	0.27	0.29
Magnesia	0.47	0.50	0.52
Alkali	1.50	0.56	0.62
Absorption, in 48 hours	6.93%	8.64%	7.00%
Elongation, at 1800° Fahr	0.4	0.67	1.40

The " C. Franklin Crown " brick is tough, hard, and close-grained. It is used to line the sides and doors of furnaces, and is selected especially to withstand the wear and tear from stoking and clinkering. " Royal Star " is a softer, coarse-grained, highly refractory brick, and useful in the arches of furnaces, where the heat is greatest. " Scioto Star " is a good refractory boiler brick, and is useful in lining the second pass of the boilers and the flues.

Fire-bricks should be laid in fire-clay, mixed to the consistency of cream. Each brick should be dipped into the clay and then hammered into its place with a heavy mason's hammer, so as to be practically in contact with the surrounding bricks on all sides. The maximum space between the bricks should not be more than $\frac{1}{8}$ in.,

but this thickness of joint should never extend over the whole bed, and the average thickness should be less than $\frac{1}{16}$ in. To accomplish this, the bricks in each course must be quite uniform in thickness.

In walls more than one brick thick, the fire-bricks may be held together by strips of $\frac{1}{16}$-in. iron, extending clear through and over them, the end of the iron being bent over as a hook at the exposed surface of the brickwork. This is required because a difference in temperature on the two sides of the brickwork would naturally produce different degrees of expansion and contraction, and the usual header and stretcher bond would give no opportunity for the brickwork to adjust itself to these movements between the inside and outside courses.

Around the clinkering doors, large bricks of two sizes are used. These should be laid with a wide overlap, which will prevent them from being loosened under the jars of clinker removal.

It is good practice to have the furnace top built of two independent brick arches separated by a thick sand joint. The lower arch receives the full heat from the fire, and protects the upper arch, which thereby will remain in its original position to hold the roof of the furnace in place.

2. Charging Apparatus.—In the first furnaces built, the refuse materials were charged by hand through openings in the top, front, or back. During the last few years, apparatus for mechanically charging the refuse into the furnace from the top have been developed successfully, particularly in America, by the Destructor Company, and are now essential parts of an economically operated plant of large size.

Bottom-charged incinerators are fired by hand through doors in the front or back of the furnace chamber. The earlier furnaces made by Meldrum were charged in front. This type was built at Seattle, and at Westmount. A typical section through a Meldrum plant is shown in Fig. 103, representing the one in Watford, England.

In the late Nineties, Heenan and Froude developed the back-fired furnace, in which the refuse was shoveled in through a door at the back, and the clinker was removed through a door at the front. It was claimed that by this procedure all the refuse was forced to pass through the fire before the ashes could leave the furnace. A plant of this type is in operation at West New Brighton. It is illustrated in Fig. 94.

Dr. Lenormand, of Le Havre, in his report, says that in 1908 the Heenan and Froude system, with some detailed improvements, offered, in his opinion, an "incontestable supériorité," because it has best solved the hygienic problem.

For top-feeding, the refuse for the earlier furnaces was stored in a large pile on a floor above them. This is unsightly, and also makes working conditions unpleasant. Leaks in the doors over the top openings allow the hot gases from the furnace to ignite the drier portions of the stored refuse, causing smoke and odor within the building. These objectionable conditions are avoided, first by storing the refuse in enclosed bins adjoining the charging doors, and then by mechanical charging.

In 1908, the authors made a trip through England and Germany, investigating furnaces for burning mixed refuse; and particular attention was given to the method of charging the refuse into the furnace. An account of the methods and their relative merits was given by Greeley in *Engineering News* (August 26, 1909), a part of which is reproduced as follows:

"It was not intended to make any comparison between the English and American incinerators, but rather to bring out the respective features of the hand-charged and mechanically-charged incinerators of the high-temperature type. These will be described and then compared on the basis of (1) cleanliness and freedom from nuisance; (2) construction; (3) operation; and (4) efficiency as measured by the value of the output. For instance, it is claimed by some that it is more difficult to build a mechanically-charged plant than a hand-charged plant; that the hand-charged plant gives better return in useful heat energy and at the same time entails a lower cost of repairs. Others maintain that the mechanically-charged plant operates more economically, in a cleaner fashion, and gives equally good steaming results. It will be interesting to see how these points work out when judged by actual results in practice.

"Greenock, Scotland

"One type of mechanical-charging device is known as the Horsfall 'Tub Feed.' In Great Britain it has been installed and successfully operated at Leeds, Newcastle-upon-Tyne, and at Greenock, Scotland; and recently the device has been fitted to two of the furnace cells at the incinerators in Zurich, Switzerland. The incinerators at Greenock illustrate the operation of this type of mechanical device as favorably as any of the others, and it will therefore be described as typical.

"The refuse burned is a mixture of garbage, ashes, rubbish, and manure, and is of average quality. As it comes to the plant it is dumped from the carts into a wooden tub set in a tipping-pit below the ground level. The tub is a strongly built square wooden box, large enough to hold about 1.5 tons of refuse, and is open at the top, with hinged lids at the bottom. Normally, these lids are closed tight by the rods and hooks from which the tub is suspended. The tipping-pit has space for four tubs. A hopper, especially designed to prevent spilling, is arranged on tracks to move off and on over the

pit. When a tub is filled with refuse, it is lifted by an electrically-operated overhead traveling crane to the platform over the clinkering floor and a little above the level of the furnace top. This platform affords sufficient space for storing eighty tubs of refuse. The opening in the top of each furnace is closed by a charging door with a water-sealed seat. Surmounting the charging door and fastened to it is a cradle of levers and balance weights. When the crane deposits a tub into this cradle, the weight of the tub causes the cradle to lower; and simultaneously the levers lift the door from its water-sealed seat and push it on guides to one side, thus allowing the lower edge of the hopper to descend a very short distance into the charging hole of the furnace. As the

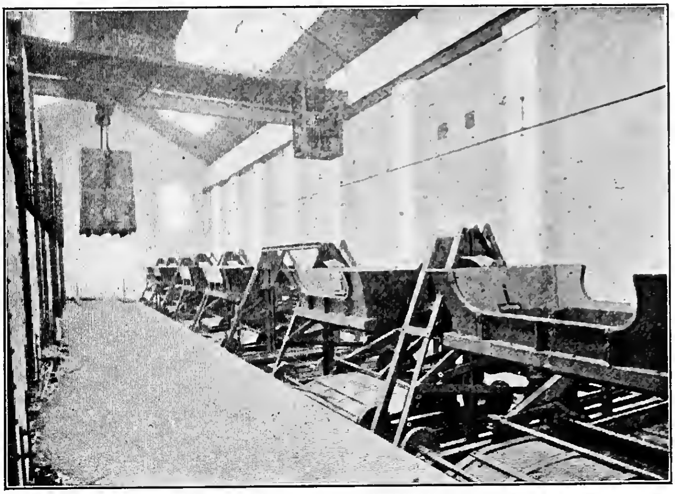


Fig. 80.—Charging Floor, Greenock Incinerator, Showing Refuse Tub and Water-sealed Doors.

cradle takes the weight of the tub off the crane, the lids in the bottom of the tub are released and the contents of the tub are discharged onto the grate below. When the tub is empty, the crane carries it back to the storage platform or the tipping-pit; and the water-sealed door, actuated by the balance weights, is drawn back to its seat. The operation occupies less than one minute. Figs. 80 and 81 illustrate this device and Fig. 82 shows the general layout of the Greenock plant.

"This type of charging device obviates all handling of the refuse at the plant, and the only manual work, above that required in an ordinary electric power station, is the clinkering of the furnace. Consequently, incineration plants fitted with this charging device are cleanly and free from unsightly refuse; and there are none of the nuisances or sources of infection incident to the storing of refuse in large open spaces or bins where men are working. The

tubs used in the plants at Leeds, Newcastle, and Greenock hold about 3 cu. yd. of refuse. When this is dumped onto the grate it forms a layer from 2 to 3 ft. thick. This thick layer requires considerable pressure on the draft, in order to thoroughly supply all parts of the burning mass with air, and therefore more power is used in unproductive work than if the thickness of the fire were kept more nearly uniform. As it requires from one to two hours to reduce one charge of refuse to hard clinker, it is not possible for the fireman to ' nurse ' the fire, and consequently some irregularities in the temperature are unavoidable. These irregularities do not appear to be excessive and are partly compensated for by the alternate charging of the grates, thus allowing the heat from one fire at the maximum point to average up with the low heat of the freshly

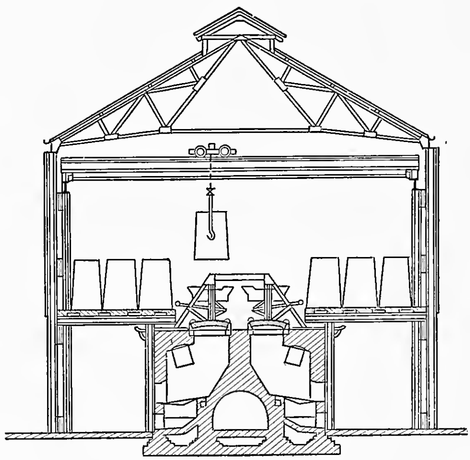


Fig. 81.—Cross-section, Greenock Refuse Incinerator, Showing Tub-feed System of Charging.

charged grate. Nevertheless, in the long run, charging such large quantities of refuse onto the grate suddenly, without adapting the composition of the refuse to the condition of the fire, must result in a lower average temperature. Just how this affects the useful heat energy will be brought out later. It is possible in smaller plants, where the crane is not worked up to its full capacity, to provide a larger number of smaller tubs, thus approaching the more nearly uniform rate of charging of the hand-fired plant; and if each tub were filled with an average grade of refuse, the efficiency of combustion would be still further increased.

" The clinker resulting from the burning of these large charges was in every way as good as that from the hand-fired plants, and showed conclusively that equally thorough combustion was obtained.

" The system of levers and balance weights used to operate the water-sealed doors is by no means ' fool proof ' and requires careful design and opera-

tion. The flues at one plant of this type were too small properly to carry away the gases of combustion. Consequently, there was quite an outward pressure on the clinkering doors and charging doors of the furnace. The heat thus driven out of the furnace evaporated the water from the water-seals and, attacking the metal directly, cracked it so that the seats were no

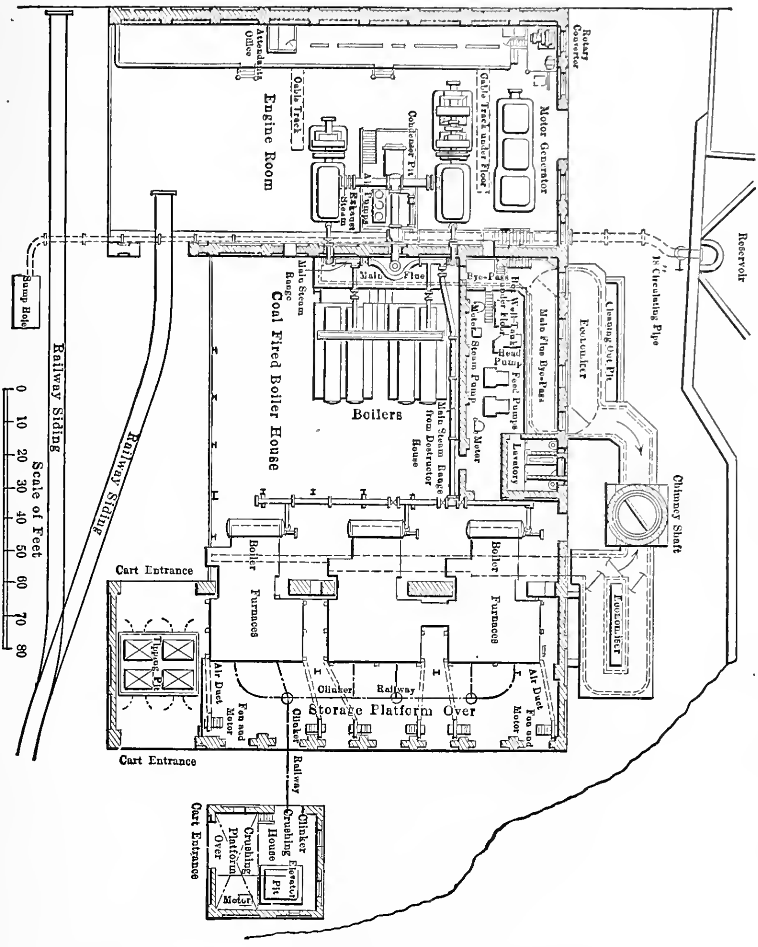


Fig. 82.—General Lay-out, Greenock Refuse Incinerator Plant. (From the *Electrical Engineer*.)

longer water-tight. The levers had become slightly distorted, so that the doors did not reseat themselves accurately, and on one occasion, while the writer was at the plant, it was necessary for the crane men to push the door into place. However, the other plants visited have worked satisfactorily without undue attention or repair, and indicate that the fault is not wholly with the mechanically-operated charging device.

"This type of device makes necessary the construction of a higher building and the installation of one or more cranes, both of which are items of increased cost. The plant cannot be operated without a crane. Experience at Greenock indicates that at least two cranes should be provided, for the only crane in service at that plant broke down for a matter of half a day and put the plant completely out of business. Only one craneman was required at any of these plants. At Leeds, burning over 50 tons per day, the craneman had plenty of time to assist in the clinkering, so that only one other man was in attendance. One man at Greenock easily operated the crane charging six grates.

"HAMBURG, GERMANY.

"In Germany, several devices for feeding refuse into incinerators mechanically have been developed. Recently, Caspersohn and Uhde, at Hamburg, have been carrying on a series of experiments on the incineration of refuse which have included the design and operation of a mechanical-feeding device. The results of the experiments have not yet been published, but the experimental furnace cell fitted with a mechanical-charging device was in operation at the time of the writer's visit to the plant.

"This experimental cell consists of a grate one square meter in area placed over an ash pit and set in the vertical brick walls of the cell. Between the cell and the main flue is a large dust catcher, shaped like an inverted cone, fitted with a sliding door at the bottom, and set high enough so that a car can be placed below the door to receive the dust and soot collected. This dust catcher is designed to be separate for each cell, and is required because the high pressure on the draft carries large quantities of dust and soot out of the cell toward the main flue above the grate. The furnace walls are arched, and there is a charging door located directly over the grate. This door is fitted with the mechanical device for delivering the refuse to the grate. It is proposed in a plant now being built in Hamburg to use a large number of cells of this design, each cell to be a separate unit, with ash pit, ash and clinkering doors, grate, charging device, dust catcher, and connection to the main flue. The main flue serves as a combustion chamber connecting the different cells, and carries the hot gases to the boilers. A typical section of such a furnace cell with charging device is shown in Fig. 83.

"The charging device consists of a long iron drum sliding inside of a shorter concentric drum of considerably larger diameter. These drums fit into a conical sheet-steel funnel, built into the brick work of the furnace top. The two drums and the funnel form two annular triangular spaces between the vertical sides of the drums and the sloping surface of the funnel. The upper of these annular spaces opens at the floor level, and the fireman rakes or shovels refuse into it from the adjacent storage platform. Raising the drum of large diameter allows the refuse to fall into the lower annular space. The outer drum is then replaced and afterward the contents of the lower space are dropped directly into the cell by raising the smaller drum. Thus the operation of charging the furnace is performed without actually exposing the grate to the outside air, and there is no leakage of hot gases from the furnace. At

Hamburg, a large open platform was built over the furnaces and the refuse was stored loosely on this platform, and from it raked or shoveled to the charging mechanism. Consequently this type of device is not wholly mechanical, but requires a certain amount of manual handling of the refuse. The drums were raised and lowered by a differential pulley operated by the fireman on the storage platform.

"This device is very simple, and has few moving parts. It is arranged so that the refuse can be mixed and graded before feeding it into the fire, and so that the size of the charge can be varied at will. Ordinarily, 1 cu. yd. of refuse is discharged at one time into the cell, and this forms a layer 3 ft. deep on the grate. The grate is built small in area, with vertical sides, so that the refuse will fall over the grate in a layer of approximately even depth and will thus present a uniform resistance to the forced draft. This charge is burned in about thirty minutes, and one man can care for the charging of two cells.

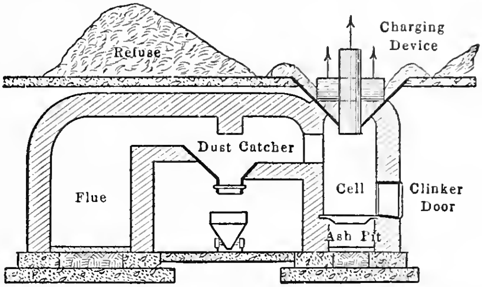


FIG. 83.—Special Charging Device, Hamburg Refuse Destructor.
(From *Engineering News*.)

One man is also required to clinker two cells. Several tests have been made with this charging device, and in them the temperature varied from 1650° to 2000° F., the extreme minimum being 1000° F., after clinkering. The temperature was recorded continuously in the main flue, and the low points in the curve corresponded closely to the times of charging the cell.

"The pressure on the draft was 6 to 7 in. of water, and large quantities of dust, amounting to about 1 cu. yd. in eight hours, were carried out of the cell to the flue. In a plant where the boiler is close to the cell and where steam is valuable, this dust settling on the boiler tubes might seriously reduce the rate of evaporation. It is not entirely possible to charge any furnace mechanically, for a long-continued time, in much smaller quantities than 1 cu. yd., because the frequency of charging, necessary to maintain the capacity of the plant, becomes burdensome. Therefore, the large charge, the depth of refuse on the grate, the high pressure on the draft, the production of the dust, and the periodic lowering of the temperature just after charging are inevitable.

"The clinker from the experimental cell was thoroughly burned and hard. The refuse lying exposed in the charging device and upon the storage platform was unsightly and liable at any time to create a nuisance. To raise the

refuse from the ground level to the storage platform required the use of a crane or of an inclined runway, both of which are elements of expense. The height of building required, while greater than for a bottom-charged incinerator, is not so great as for the plant using the tub-feed device.

" Herbertz Device.

" Herbertz, a contractor, with headquarters at Cologne, has developed a device for charging refuse into incinerators. To demonstrate the success of his design, he has built an experimental plant at Cologne, which operates for the enlightenment of municipal authorities who are considering the construction of a refuse incinerator. Herbertz has a plant in operation at Kiel and one under construction at Frankfort.

" The plant at Cologne consists of five separate grates, built adjacent to each other. A common combustion chamber extends along the back of these grates and the hot gases from the grates pass directly through this chamber on to two water-tube boilers. The grates each have an area of about $\frac{3}{4}$ sq. yd., and are made of an iron plate perforated with 24 holes for the forced draft. The cells or grates all front on one clinkering room. Above this clinkering room is a large sheet-iron bin, the bottom of which has a slope of about 45° downward to the top of the furnace. A vertical conveyor lifts the refuse into this bin. At the bottom of this slope, and forming one side of the bin, is a vertical sheet-iron wall; and about 3 ft. from this is a similar sheet-iron wall. Between the two walls are placed iron chutes which lead through the furnace top to the grates. An operator on a platform over the combustion chamber rakes refuse down from the bin into the chutes, and keeps them always full of refuse. The emptying of a charge into the cell is effected by means of a sliding door in the chute, which is operated by a lever from the clinkering floor. A set of signals indicates to the operator above whenever a chute becomes empty.

" It was customary at the Cologne plant to charge about 1 cu. yd., of refuse on to the grate at a time. This gives a depth of refuse on the grate of about 4 ft., and requires a pressure on the draft of as much as 12 in. of water. Each cell has a capacity of about 10 tons of refuse per day. The combustion of refuse was thorough, and the recorded temperatures on the many tests, which have been made with a variety of refuse from many cities, vary from 1200° to 2000° F. The storage bin can be made large. At Frankfort, where the plant will consist of several units, each similar to the plant at Cologne, the bin has a capacity sufficient to hold the refuse collected in twenty-four hours. With this type of charging device, the refuse is kept away from the operators and well out of sight. The operator above can vary the size of charge, as directed by the fireman, and, to a certain extent, can determine the grade of refuse needed for any particular charge. The actual charging of the furnace and the opening of the charging door is performed between the vertical steel walls when the doorways through these are closed, and thus the leakage of furnace gases out into the working rooms is materially reduced.

" The Herbertz plant at Kiel has been in operation since November, 1906. It consists of three units, each unit having six cells, one combustion chamber

and one water-tube boiler. In each cell is a grate having an area of about 1 sq. yd. Over each furnace is a storage bin, each having a capacity of about 100 cu. yd. The plant has a rated daily capacity of 185 tons, and burns an average of 125 tons per day. The scheme of storing the refuse in closed bins, out of sight and away from the workmen, was developed further at Kiel than at Cologne. The householders deposit the refuse in cans and these cans are collected on large two-horse wagons having a capacity of 44 cans each. No attempt was made to grade the refuse in the cans. The wagons enter the plant over an inclined roadway and deliver the cans on a platform at the elevation of the top of the storage bins. The tops of these bins are entirely enclosed, and each one is fitted with a closed hopper, built to receive the refuse cans and to discharge the contents of the cans into the bin below. Figs. 84 and 85 illustrate how the refuse is received at the plant and placed in

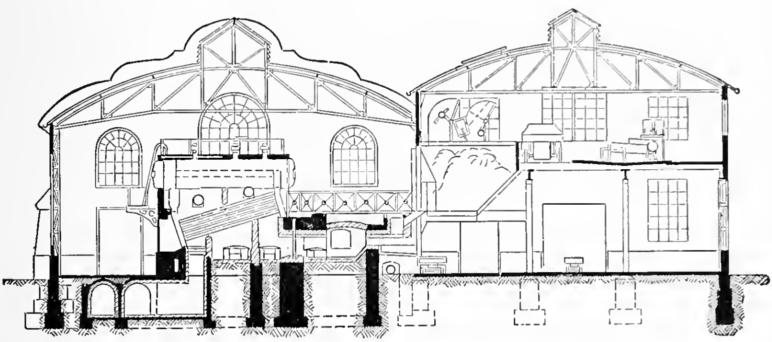


FIG. 84.—Section through Herbertz Incinerator, Kiel, Germany.
(From *Engineering News*.)

the bins. The bins themselves are built of sheet-iron, and are similar to those at Cologne. They slope at about 45° to the top of the furnace, over the clinkering doors, and feed into chutes which guide the refuse into the cells. The chutes are filled and discharged just as they are at Cologne. The feature of the plant is that the refuse, from the time it is placed in the cans at the houses, is nowhere exposed to sight until it comes out of the furnace as clinker.

" This method of unloading the refuse in the cans at the plant, although it saves the expense of operating a crane, nevertheless requires the steep haul up an inclined approach, and increases the labor at the plant over that required with the tub feed. The force required during the day to deliver the refuse from the wagons to the bins comprises four workmen, and an assistant emptying cans, and eight women cleaning the empty cans. The women cleaning the cans should not be charged against this system, because in any system the receptacles in which the refuse is collected or stored should be cleaned.

" As compared with a hand-fired plant, this system of charging the furnace requires a greater height of building and the expense of an inclined roadway. As compared with the tub-feed device, it requires an overhead storage bin in

addition to the cans or tubs used on the collecting wagons; but does not require the use of an electric crane. After the refuse is placed in the storage bins 24 men are required to operate the plant, including two machinists and two boiler attendants. If the boiler attendants and machinists are not included, and if two men per shift are included for unloading cans, the labor reduces to eight men per shift on the incinerator proper.

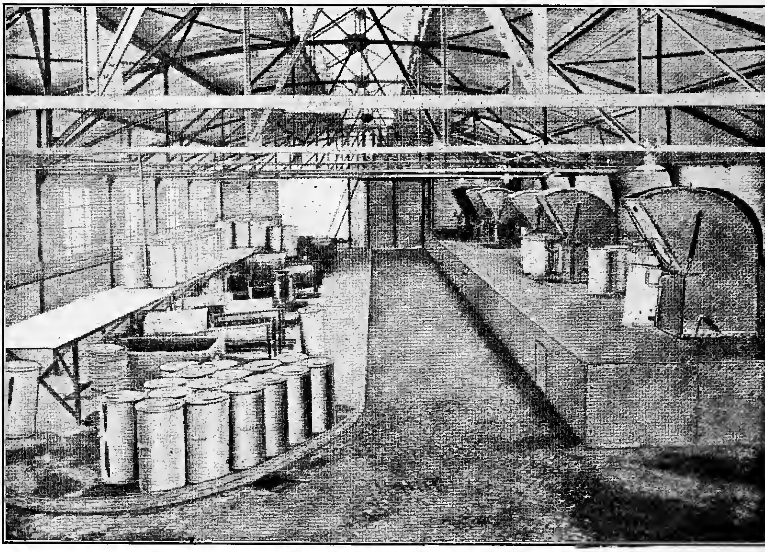


FIG. 85.—Refuse Receiving, Dumping, and Can-washing Floor, Kiel Incinerator.

(From *Engineering News*.)

"WIESBADEN, GERMANY.

"A fourth type of charging device has been developed by Berlit, engineer in charge of refuse disposal at Wiesbaden, Germany. This plant consists of six cells, built in pairs, and has a capacity of about 100 tons per day. The furnace top is floored over strongly and divided longitudinally into two rooms by a strong vertical wall. The cart bodies containing the refuse are hoisted by a crane and emptied on the platform on one side of the wall. On the other side of the wall are located the charging holes leading to the grate. For each two charging holes, there is one chute or tube which can be swung over either charging hole. This chute leads through the dividing wall into the refuse storage room at a height of about 7 ft. from the floor, the chute being hinged a few feet out from the wall. Directly below the chute there is a depression in the floor of the storage room in which sets a cylindrical charging can. The workmen rake the refuse, piled loosely on the floor, into this can; and then by

means of a pulley and guides, raise the can until it empties the refuse it contains through the chute into the cell.

" With this type of device, the refuse is piled openly in the storage room, and the workmen come in actual contact with it. This, while being a sanitary disadvantage, allows the men to deliver a fairly uniform grade of refuse to the furnace and to vary the quality of a charge to suit the fire. The cans do not contain more than 1 cu. yd. of refuse when full.

" When the writer inspected the plant, the refuse slid through the chutes easily, and there was no great leakage through the feed holes during charging, although the chute did not fit tightly over the door. It is possible, however, that at times these chutes would clog and cause trouble and delay.

" This type of charging device does not do away with the crane, nor the open storage of refuse, and, except that it does away with the physical discomfort of hand-firing, has little advantage over the hand-charged plant. Each cell was charged every 40 min. with about 1 cu. yd. of refuse. The draft was furnished to each cell by a separate motor fitted with a controlling device for changing the speed of the motor, and so the pressure of the draft, to suit the condition of the fire. Mr. Berlit stated that only about $1\frac{1}{2}\%$ of the total electrical output of the plant was used in the forced draft.

" The Horsfall tub-feed, the Hamburg device, the Herbertz system, and the mechanism in use at Wiesbaden represent practically everything that has been developed to date in the way of special devices for charging refuse into incinerators. In addition to the investigations of the mechanical-feeding devices, as described above, the writer visited hand-fired plants at Zurich, Switzerland, at Watford, Wood Green, and Saltley, England, and at Scranton, Seattle, Vancouver, and West New Brighton in this country. Details of the operation of several other plants of both types were obtained by correspondence.

" Hand Charging.

" Since a good deal has recently been published about incinerators charged by hand, and as there are several of these in operation on this continent, a detailed description of this type will not be presented. It is enough to say that with incinerators of this type, the refuse is commonly dumped into a storage bin opening at the level of the clinkering floor. The refuse is then shoveled by hand on to the grate and the clinker withdrawn by the doors through which the furnace was charged, or the doors on the opposite side of the grate. Although it is possible with hand-firing to keep the temperature of the fire even, by proper regulation of the charge and by frequently applying small charges, in practice this cannot be carried to any great extent on account of the possible inrush of cold air when the furnace door is open. The temperature is kept uniform to a considerable extent by having a group of three or four cells in one common furnace which can be charged alternately, so that the general activity of the fire is not seriously reduced. Any of the special charging devices described might be used with such a multi-cellular furnace.

"Comparison of Charging Methods.

"Before proceeding with a more detailed comparison of the mechanically-charged and hand-charged incinerators, it should be stated that the completeness of such a comparison depends to a considerable extent on the quality and value of the refuse. Two plants of equally good design and economy may show very different results when compared as to efficiency of combustion, if the refuse burned at one of the plants is of greater heat value than the refuse burned at the other. Complete records of the character and composition of the refuse burned at the plants inspected are not available. At some of the installations extensive records of the composition of the refuse have been kept; but even these vary considerably from one season to another, and do not always enable one to interpret the results of records of operation in a true and complete way. Such plants as the Herbertz plant at Cologne, where the refuse from about twenty different cities has been tested, give dependable data in which variations in the quality of the refuse are obscured in the general average of results. In general, it may be stated that refuse collected in Germany and in America will have a somewhat lower calorific value than English refuse. In spite of this lack of detailed information about the quality of refuse burned, it is, nevertheless, thought that the general tendencies of the types of incinerators compared will be sufficiently marked, when averaged for a large number of plants, to largely outweigh the variations in the character and fuel values of the refuse. It should also be stated that the intelligence of the labor affects the total efficiency of the plant. In this particular, incinerators with special charging devices have a certain advantage over hand-fired plants, in so far as they require a more skilled and intelligent class of labor to operate them.

"(1) *Cleanliness or Freedom from Nuisance.*—Probably the most unclean type of refuse incinerator is the hand-fired top-fed plant. In plants of this type, the refuse is stored on platforms above the furnace, and the men feeding the fires frequently have to walk over and through the refuse. At Hamburg and Zurich, the openings into the furnaces were closed, after charging, by jamming refuse tightly into the feeding holes. This was often done by stamping with the feet, and was an unclean operation. Furthermore, the refuse was thus left to cook over the grate, and a most unpleasant odor resulted.

"In the back-fed and front-fed types of incinerator it is, of course, necessary for the firemen to come in physical contact with the refuse. This is more or less unpleasant, depending upon the character of the refuse. At one of the plants visited the refuse was so dusty during the summer that hand-firing was made endurable only by sprinkling the refuse with water as it was dumped into the storage bin. In England, there was considerable discussion over the relative cleanliness of the front-fed and back-fed types, but the writer has found little to choose between them on that score.

"The cleanest plants visited by the writer were the mechanically-charged plants, and particularly the tub-fed plants. In these, the refuse is not handled at all, but is conveyed in closed containers and discharged directly into the furnace. There was no refuse visible at any part of the plant. There

seems to be no good reason why the fixed containers used in charging the furnace could not be either used at the houses or carried on specially-designed wagons, somewhat as at Kiel, through the city collecting the refuse from the houses, stores, schools, etc. This would avoid dumping from the collecting carts to the fixed containers at the plant, and the refuse collected in the tubs or containers could be graded as the wagons passed from house to house.

" In plants charged mechanically it is necessary to keep a high pressure on the draft. In spite of this, at only one plant was there any nuisance from leakage through the charging holes.

" The writer found that the higher building required in the mechanically-charged plants to accommodate the crane and charging device, considerably added to the airiness of the building. It is the opinion of the writer that the mechanically-charged plants are the cleanest and the most sanitary for the men operating the furnace.

" A refuse incinerator, however, should be free from nuisance, not only to those operating the plant, but also to the people living and working in the neighboring buildings. About no one of the plants visited was there any decided odor, and it was evident that in practically all well-built and well-operated incinerators, of both top-charged and bottom-charged types, refuse could be burned without offense to the community.

" It is necessary, with mechanical charging and high pressure on the draft, to take great precautions to keep soot and dust from being blown out of the furnace and up the chimney; results in practice indicate that this is entirely feasible. The writer found little to choose between top- and bottom-charged incinerators on the basis of nuisance to the community.

" (2) *Construction.*—The simplest type of incinerator to build is the front-fed type. Incinerators built for top charging must have an opening in the arch over the grate, and require careful and substantial construction to accomplish this securely. The bottom-charged plants, and particularly those fired in front, have the charging doors in the vertical walls of the furnace and weaken the furnace structure very little. The top-fed plants require a strong grate or a back hearth to guard against fracture from the fall of the refuse. This is true even more with the mechanical-charging devices, which frequently discharge the refuse from five or more feet above the grate level. These features add to the cost of the top-charged plants. Furthermore, the inclined approach, belt conveyor, or crane used to lift the refuse above the furnace top increases the cost of the top-charged plant. Consequently, the top-charged incinerator should generally cost more than the bottom-charged type. Actual costs of construction are misleading unless one knows the local conditions controlling the building of the plant. Nevertheless, the following figures serve to throw some light on the relative construction costs of these two types of incinerators. Most of these costs are for English incinerators, and cannot be used directly for American practice. It is only when used comparatively that they have value. Other features, such as style of building, also affect the total cost of any particular plant.

" The data presented in Tables 98 and 99 are taken from a paper by Mr. J. T. Fetherston, read before the American Society of Civil Engineers, December, 1907; from the ' Minutes of Evidence,' Vol. 5, 1908, of the Royal

Commission on Sewage Disposal, and from 'Refuse Disposal and Power Production,' by W. Francis Goodrich. The individual results differ widely, and show how local conditions affect the cost of construction. There may be conditions for which a top-charged plant is the more economical. In general, however, the results point to the fact that the top-charged incinerators cost about 10% more than bottom-charged incinerators.

TABLE 98.—AVERAGE COST OF CONSTRUCTION OF BOTTOM-CHARGED INCINERATORS

Plant	Rated capacity, in tons of 2000 lb. per day	Cost		Authority
		Total	Per ton	
Aldershot	50	$5,800	$116	Goodrich
Burslem	33	18,950	574	Fetherston
East Ham	67	61,700	920	Goodrich
Eccles	53.5	22,000	412	"
Epsom	53.5	22,100	412	"
Fulham	135	82,124	610	Fetherston
Heywood	27	24,300	900	Goodrich
Hyde	80	34,000	425	"
Ilkey	22.5	7,020	312	Fetherston
Kettering	28	25,480	910	"
Kings Norton	100	73,500	735	"
Lytham	27	11,700	434	Goodrich
Manchester	33	12,700	385	"
Radcliffe	40	16,000	400	"
Rathmines	67	35,200	525	Fetherston
Salisbury	30	14,600	485	Goodrich
Seattle	60	36,000	600	Morse
Sheerness	26	17,150	635	Fetherston
Swansea	71	53,900	756	"
Taunton	60	19,500	325	Goodrich
Vancouver	48	35,000	730	Greeley
Watford	53.5	33,000	618	Goodrich
West New Brighton	60	......	about 1000	Nutting
Weymouth	53.5	19,500	365	Goodrich
Worthing	28	21,450	765	Fetherston
Wrexham	53.5	11,324	211	"

" A mechanical-charging device fitted to a top-fed plant is an added element of cost. The incinerator at Newcastle, fitted with the Horsfall tub-feed, cost about $48,000, and has a rated capacity of 67 tons, which gives a cost per ton of about $715. At Greenock, the incinerator, with Horsfall

tub-feed, cost $95,000, and has a rated capacity of 120 tons, giving a cost per ton of $790. The cost of the mechanically-charged plant at Leeds was only $375 per ton; but this plant was built adjacent to an old hand-charged incinerator where it was possible to use the flues, boilers, and chimney of the old plant. Mr. George Watson, of the Horsfall Co., figured roughly on $17,000 as the cost per cell of a tub-fed incinerator. This, on a basis of 26 tons per cell per day, as at Leeds, gives a cost per ton of about $650. These figures indicate that a mechanically-charged incinerator may cost in the neighborhood of $650 to $700 per ton under conditions which would require an expenditure of about $550 per ton for the hand-fired bottom-charged plants. This difference, at 5% annual interest and 310 working days per year, reduces to about 2 cents per ton. The figures given for the cost of construction are for the whole plant, including cells, building, chimney, runway, crane, and hopper; but do not include land or any adjacent electric plants, sewage-pumping stations, etc.

Table 99.—Average Cost of Construction of Top-charged Incinerators

Plant	Rated capacity, in tons of 2000 lb. per day	Cost		Authority
		Total	Per ton	
Accrington	60	$60,000	$670	Goodrich
Belfast	134	49 000	366	Fetherston
Brentford	60	40 000	670	Goodrich
Bristol	120	60,000	500	"
Bromley	50	23 900	478	Fetherston
Burton-on-Trent	28	23 000	820	"
Dalmarnock, Scotland	84	66,700	794	Goodrich
Eastbourne	75	33 000	442	"
Leamington	75	30 500	405	"
Leyton	100	43 160	430	"
Llandudno, Wales	28	27 980	990	Fetherston
Ruehill, Scotland	89	100 220	1130	"
Saltley	95	52 000	547	"
Shoreditch	112	100 500	900	"
Southwick	62	45 000	725	Goodrich
Stafford	50	19,500	390	"
St. Pancras	100	102 900	644	Fetherston
Stockton-on-Tees	22.5	15 000	670	"
Walthamstow	112	49 000	438	"
Wandsworth	78	24 500	315	"
Westminster Boro'	80	50 180	630	"
Winchester	20	12,400	620	Goodrich

"(3) *Operation.*—Data showing the force required to operate the different types of plants and the cost of repairs have been obtained and are presented in Tables 100 and 101, which follow. Table 100, hand-charged incinerators, gives the tons of refuse which can be handled per man per hour. All of the hand-fired plants are grouped together and averaged for comparison with the mechanically-charged plants. There is no great difference in this respect between the hand-fired bottom-charged plants and the hand-fired top-charged plants. Actual quantities of refuse burned, instead of rated capacities, are used in reducing the results to a man-hour basis.

TABLE 100.—LABOR REQUIRED IN THE OPERATION OF HAND-CHARGED INCINERATORS

Plant	Top-charged or bottom-charged	Number of men per shift	Tons of 2000 lb. burned per day	Tons per man-hour
Accrington	Top	5	40	0.34
Saltley	Top	3	60	0.83
Seattle	Bottom	4	60	0.63
Vancouver	Bottom	2	50	1.00
Watford	Bottom	2	30	0.63
Westmount	Top	3	30	0.42
Wood Green	Bottom	2	35	0.73
Zurich	Top	10	160	0.67
Average	....	....	....	0.66

TABLE 101.—LABOR REQUIRED IN THE OPERATION OF MECHANICALLY-CHARGED INCINERATORS

Plant	Number of men per shift	Tons of 2000 lb. burned per day	Tons per man-hour
Greenock	4	110	1.14
Hamburg experimental plant	2	60	1.25
Kiel	8	125	0.65
Leeds	2	53.5	1.12
Newcastle	3	60	0.83
Wiesbaden	5	110	0.90
Average	....	....	0.98

"The average is brought down by the low figure for Accrington, which has a close, poorly ventilated clinkering room where clinkering is hot and heavy work; and by the low figure for Westmount, where the plant is working considerably below its rated capacity. Omitting these two, the average becomes 0.75 ton per man per hour. Mr. Fetherston sums up his study of 27 plants, only one of which was mechanically-charged, by saying that 'each man employed would handle 0.88 short ton per hour, . . . At an easy rate of working there should be no difficulty in destroying 0.75 ton per hour per man." The writer's investigations bear out this conclusion.

"As compared with this, Table 101 shows the quantity of refuse handled per man per hour in the plants fitted with mechanical-charging devices.

"Herbertz, who is building a mechanically-charged plant at Frankfort, has stated that the guaranteed force required to operate each unit of four grates is three men per shift of eight hours. At the capacity planned for, as based on experiments made at Cologne, this averages to 1.10 tons per man-hour.

"These tables indicate that with a mechanical charging device about one-fifth of a ton more per man per hour can be handled than without it. Assuming 25 cents an hour for labor, this difference amounts to 5 cents per ton in favor of the mechanically-charged incinerators. For plants fitted with the Horsfall tub-feed this figure may be slightly greater.

"The cost of repairs for incinerators varies considerably from year to year and no very definite results can be expected. The mechanically-charged plants have most of them been built within the last two years, and there are very few data on cost of repairs. The plants were grouped in Tables 102 and 103 according to whether they are bottom-charged or top-charged, because top-charging in general is harder on the grate and hearth, and because the top charged plants are more nearly analogous to the mechanically-charged plants. The costs given in the tables are taken from the testimony of Mr. W. F. Goodrich before the Royal Commission on Sewage Disposal, from Mr. Fetherston's paper, or were furnished by Mr. H. Norman Leask, of Manchester, England. A few of them were taken from English pamphlets on refuse incineration.

"On a basis of 310 working days in a year, these average results reduce to about 0.50 cent per ton for repairs for the bottom-charged plants and 2.5 cents per ton for hand-fired top-charged plants, a balance of 2 cents per ton in favor of the bottom-charged incinerator.

"For the mechanically-charged plant at Leeds, now in its fifth year and burning 53.5 tons per day, the repairs for the year 1908 amounted to $90, or about $1.68 per ton per year, which is equivalent to 0.54 cent per ton of refuse burned.

"(4) *Efficiency, and Value of Output.*—Perhaps the most satisfactory way to compare different types of incinerators is on the basis of the value of the output. The usual output of a refuse incinerator comprises chiefly the clinker and the available heat energy. Both of these are largely dependent upon the quality of refuse burned, and comparative results should be reduced to the same grade of refuse. This, however, is practically impossible to do,

TABLE 102.—APPROXIMATE COST OF REPAIRS FOR BOTTOM-CHARGED INCINERATORS

Plant	Tons of 2000 lb. burned per day	Cost of Repairs per Year	
		Total	Per ton
Aldershot	13	$0.90	$0.07
Birmingham	37	40.00	1.08
Burslem	40	7.00	0.17
Gosport	33	243.00	7.38
Grays	12	25.00	2.08
Hereford	12	21.00	1.75
Levenshulme	50	8.00	0.16
Lytham	13	5.00	0.38
Manchester	60	122.50	2.05
Radcliffe	39	85.00	2.18
Sheerness	14	14.00	1.00
Watford	30	50.00	1.67
Weymouth	20	8.40	0.42
Worthing	21	32.00	1.52
Wrexham	33	21.00	0.64
Average	....	....	$1.50

TABLE 103.—APPROXIMATE COST OF REPAIRS FOR TOP-CHARGED INCINERATORS

Plant	Tons of 2000 lb. burned per day	Cost of Repairs per Year	
		Total	Per ton
Belfast	90	$490.00	$5.25
Bolton	50	68.00	1.36
Cambridge	29	290.00	10.00
Fulham	118	14.80	12.50
Hackney	142	22.50	15.80
Leamington	39	73.00	1.87
Rotherham	56	315.00	5.62
Royton	16	146.00	9.15
Southampton	45	340.00	7.55
Average	....	....	$7.90

and only general tendencies can be noted by tabulating and averaging large numbers of results covering a wide range of conditions.

"The writer's observations lead him to conclude that the value of the clinker is little affected by the type of incinerator in which it is burned. Thus, at Zurich, a hand-charged top-fed plant, the clinker and ash were sold for concrete and artificial stone, and brought 35 cents per cubic yard. The clinker from the mechanically-charged plant at Newcastle was crushed and used in city streets as a surface grit to prevent horses from slipping. The clinker at Greenock was crushed, graded, and sold, and was of excellent quality, hard and durable. The clinker from the hand-charged plant at Watford was used successfully for building sewage-disposal works (filter beds). Local conditions affect the value of clinker so greatly that, relatively, the method of charging has almost no effect.

"On the other hand, the method of charging has an important influence on the value of useful heat energy obtained from the refuse. Tables 104 and 105 indicate the extent to which the useful heat energy returned is influenced by the method of charging.

TABLE 104.—EVAPORATION OBTAINED IN TESTS OF HAND-FIRED, TOP-CHARGED INCINERATORS

Plant	Date of erection	Pounds of water evaporated per pound of refuse, from and at 212° Fahr.
Accrington	1900	1.39
Ashton-on-Lyne	1901	0.78
Birmingham (Montague St.)	1879	1.56
Bradford (Hamerton St.)	1898	1.25
Bury	1901	0.94
Canterbury	1899	1.54
Fleetwood	1900	1.19
Fulham	1901	1.30
Hackney	1902	1.42
Llandudno	1898	0.86
St. Helens	1899	1.54
Shoreditch	1897	0.96
Saltley	....	1.82
West Hartlepool	1901	1.25
Wandsworth	1897	1.24
Westmount	1899	1.36
Average	....	1.27

"Nineteen tests were made at the mechanically-charged plant at Cologne, and the average actual rate of evaporation was 1.01 lb. of water per pound of

refuse at 140 lb. steam pressure. This is equivalent to about 1.25 lb. of water per pound of refuse, from and at 212° F. The Greenock plant, when tested, gave an evaporation, from and at 212° F., of 1.41 lb. of water per pound of steam. At Kiel the evaporation, from and at 212° F., is about 0.95 lb. of water per pound of refuse, and at Wiesbaden about 1.08. These results indicate that hand-charging will give an evaporation, from and at 212° F., per pound of refuse, of about 0.40 lb. of water more than can be obtained with a mechanical-charging device.

Table 105.—Evaporation Obtained in Tests of Bottom-charged Incinerators

Plant	Date of erection	Pounds of water evaporated per pound of refuse, from and at 212° Fahr.
Ayer	1903	1.58
Burnley	1902	2.00
Burslem	1889	2.16
Darwin	1899	1.48
Eccles	1904	1.35
Grays	1901	1.22
Gloucester	1902	1.74
Hereford	1897	1.67
Kings Norton	....	2.63
Lancaster	1901	1.63
Mansfield	1903	1.80
Nelson	1900	1.77
Northampton	1903	1.32
Preston	1903	1.70
Rathmines	....	1.78
Rochdale	1894	1.81
Salisbury	1902	1.23
Seattle	1907	1.00
Watford	1903	1.56
West New Brighton	1908	1.32
Average	....	1.67

"Tables 106 and 107, with but two exceptions, were compiled from the testimony of Mr. W. F. Goodrich before the Royal Commission on Sewage Disposal. They show the saving in coal at sewage-pumping stations or electricity works where refuse is used to generate part of the steam.

"These two tables confirm the evidence of Tables 104 and 105 that the value of the useful heat from refuse used to raise steam is greater for the hand-fired bottom-charged plants than for the top-charged plants.

TABLE 106.—APPROXIMATE ANNUAL SAVING IN COAL, DUE TO THE USE OF STEAM GENERATED AT TOP-CHARGED INCINERATORS

Plant	Refuse burned, in tons per day	Annual Saving in Coal	
		Total	Per ton
Bolton	50	$1130	7.3 cents
Leamington	39	900	5.8 "
Leyton	160	1090	2.2 "
Newmarket	12	1090	29.4 "
Walthamstow	67	3150	15.0 "
Westmount	30	3000	33.3 "
Average	....	....	15.5 cents

TABLE 107.—APPROXIMATE ANNUAL SAVING IN COAL, DUE TO THE USE OF STEAM GENERATED AT BOTTOM-CHARGED INCINCERATORS

Plant	Refuse burned, in tons per day	Annual Saving in Coal	
		Total	Per ton
Aldershot	13	$1700	42.1 cents
East Ham	33	4850	47.4 "
Eccles	31	1700	17.6 "
Epsom	13	1800	44.6 "
Gosport	33	1950	19 "
Hereford	12	1950	52.5 "
Lytham	13	1330	33 "
Taunton	22	560	8.2 "
Watford	30	1600	17.2 "
Weymouth	20	1820	29.3 "
Average	....	....	31.1 cents

" Mr. W. Goodrich, in his book entitled 'Refuse Disposal and Power Production,' presents a table showing the number of electrical units generated per ton of refuse destroyed at twenty combined electricity and destructor works. If the top-charged and bottom-charged plants listed in these tables be averaged separately, the results would show an output of 30 kw.-hr. per short ton for the top-charged incinerators, as against 40 kw.-hr. per short ton for the bottom-charged incinerators.

" These results have been bettered considerably in more recent installations. Tests made on the top-charged plants at Bradford and Hackney, and

on the mechanically-charged plant at Greenock, developed 60, 50, and 80 kw.-hr. per short ton of refuse burned, respectively, the average being 63.3 kw.-hr. per ton. The bottom-charged incinerators at Stoke-upon-Trent, Woolwich, Preston, and St. Albans developed, on tests, 97, 90, 90, and 92 kw.-hr. per ton, respectively, the average being about 92 kw.-hr.

"In comparing the efficiencies of incinerators on the basis of electrical units generated, the efficiency of the machinery becomes a factor, as well as the grade of the refuse, and the results are not so reliable as the evaporative tests. Nevertheless, the evidence is strong that with bottom-charging, as compared to top-charging, a greater output of electrical units may be expected. This difference may amount to 20 kw.-hr. per short ton of refuse.

"Most of the above results are confined to hand-fired plants. Such results as are given for mechanically-charged plants indicate that these do not differ greatly from results obtained with the hand-fired top-charged plants, and that, as compared with bottom-charged incinerators, the results tabulated for hand-fired top-charged plants are a good index of the efficiency of the mechanically charged plant. If we assume steam to be worth 3 cents per 100 lb. and electric power to be worth 1 cent per kw.-hr., then we have, as the value per ton of bottom charging over top charging, the following results for each of the bases taken for comparison:

	Cents per ton
On basis of evaporation	24
On basis of saving in coal	15.6
On basis of electrical output	20
Average	19.9

"It must, however, be remembered that, except for the results based on the annual saving in coal, the results are based chiefly on test runs and not on everyday working conditions. In view of this fact, the writer believes the value of hand-firing in bottom-charged plants over top-charged plants is not generally over 13 to 15 cents per ton. This is particularly true because, in steam plants using refuse for fuel, it is the minimum power developed that determines the true rating, and it is only in works where a considerable portion of steam is raised in coal-fired boilers that the irregularities in the fuel value of refuse can be somewhat reduced. The saving in coal should be a good index of the value of the refuse as fuel in such works. This element of value in bottom-charging over top-charging applies only where steam is valuable.

"These various points may be summarized as follows:

"(1) Cleanliness: Mechanical charging offers the greatest opportunity for cleanliness, within and about the plant, of any type of incinerator, and causes no more nuisance to the community.

"(2) Construction: A mechanically-charged incinerator, other things being equal, will cost about $125 per ton of rated capacity more than a bottom-charged incinerator. This is equivalent to a difference of about 2 cents per ton of refuse burned.

"(3) Operation: By using a mechanical-charging device, about one-fifth of a ton of refuse per man-hour can be handled more than with hand-firing in bottom-charged incinerators. This is equivalent to about 5 cents per ton of refuse burned. A mechanically-charged plant may cost from 1 to 2 cents more per ton for *repairs* than the bottom-charged plant.

"(4) Value of Output: There is little difference in the value of the clinker from the different types of incinerators. The useful heat energy from the hand-fired bottom-charged plants is worth from 13 to 15 cents per ton of refuse burned more than the useful heat energy from mechanically-charged incinerators.

"Within the range of capacities of the plants investigated (say up to 100 tons daily capacity), and in communities where steam has a distinct value, the evidence presented indicates that hand-fired bottom-charged incinerators are the most economical type. In communities where steam raising is not of prime importance, or where power cannot be readily marketed, mechanical charging has many advantages. Some of these cannot be expressed in terms of money value. Thus, for each community, the controlling factors must be determined, and the type of incinerator best adapted to these conditions must be selected.

"It is only fair to state, however, that special devices for charging high-temperature incinerators are a comparatively recent development in refuse incineration, and have not yet been developed to the same extent to which hand-charging has been carried. The facts that the sudden fall of a considerable charge of refuse may be received on a drying hearth at the back of the furnace and thus kept from submerging the burning mass on the fire-grate proper, and that the grade of refuse may be kept uniform even in the tub-fed type of plant, by taking special care to fill each container with the proper proportions of each constituent of refuse, leads one to believe that the amount of useful heat in the refuse may be developed in mechanically-charged plants to more nearly the same extent to which it is developed by hand-firing. Add to this the consideration that mechanical charging permits of greater cleanliness in operation and compels the use of skilled labor, and it becomes evident that, for some conditions, mechanical charging may be the more advantageous."

Since 1908, when the foregoing account was prepared, mechanical devices for charging refuse have been further improved. Particularly, due to the development of mechanical clinkering, the efficiency of incineration with mechanical charging has been increased, so that at present the temperatures appear to exceed those of hand-charging, because the time required for opening and closing the furnace doors and the inrush of cold air is reduced to a minimum.

The most recent devices for charging refuse into high-temperature incinerators are those at Clifton, Paterson, Atlanta, Savannah, and San Francisco. At the Clifton plant the wagons dump into a bin from which the refuse is raked into a rectangular box, set just below the floor level. When this box is full it can be pushed by a hydraulic ram

into the furnace, several feet above the grate. When the box is inside the furnace, its bottom is withdrawn and the charge falls on the grate below. The device is illustrated in Fig. 96.

In the other four plants, the refuse is discharged into deep storage pits at the ground level. Electrically-operated grab-buckets lift the refuse from the pit and carry it to charging containers above the furnace, one of which is set over each grate. A charge is delivered to the grate by opening a hydraulically-operated sliding door in the bottom of the container. This apparatus is illustrated in Fig. 86.

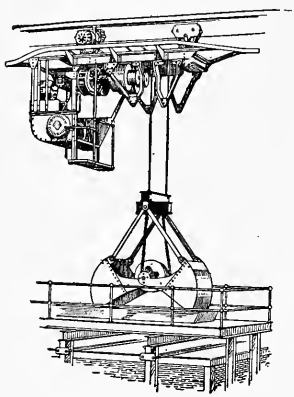


FIG. 86.—Grab-bucket. (From *Engineering News.*)

Mechanical devices for charging have also been operated successfully on garbage furnaces; the one designed by Lewis is illustrated in Figs. 87 and 88. The wagons discharge garbage into a steel hopper set below the delivery floor. This hopper must have sufficient capacity for one day's delivery. A pusher or ram works back and forth at the bottom, and at each forward stroke discharges a small quantity of garbage on the drying hearth. The rate of charging can be varied by changing the speed of the eccentric.

3. Air Supply.—As already computed, air must be supplied for the combustion of mixed refuse at a rate of from 4.5 to 6.0 lb. per pound of refuse. For burning garbage (not mixed refuse) with coal, however, the quantity of air depends on the nature of the garbage and the quantity of coal burned with it. If we assume the garbage to contain 5% of carbon, 1% of hydrogen, 4% of oxygen, and sufficient moisture to require, for odorless combustion, 400 lb. of coal per ton of garbage, then the following theoretical quantity of oxygen is required per pound of garbage. (See pages 315 and 316 for method of calculation and also Table 94.)

Oxygen required to burn the carbon......	2.67×0.05	$= 0.13$ lb.
Oxygen required to burn the hydrogen...	8.0×0.005	$= 0.04$ lb.
Oxygen required to burn the coal........	$2.56 \times 0.8 \times 0.2$	$= 0.43$ lb.
Therefore, the required oxygen per pound of garbage......		$= 0.60$ lb.

In the first line of this computation, 2.67 is the weight, in pounds, of oxygen required to burn 1 lb. of carbon to CO_2, and the figure 0.05

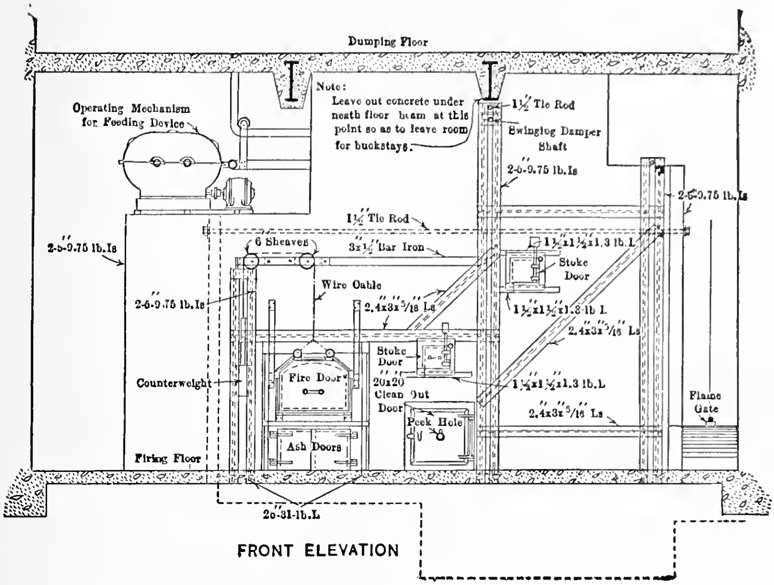


FIG. 87.—Lewis and Kitchen Garbage Furnace with Automatic Charging Device.

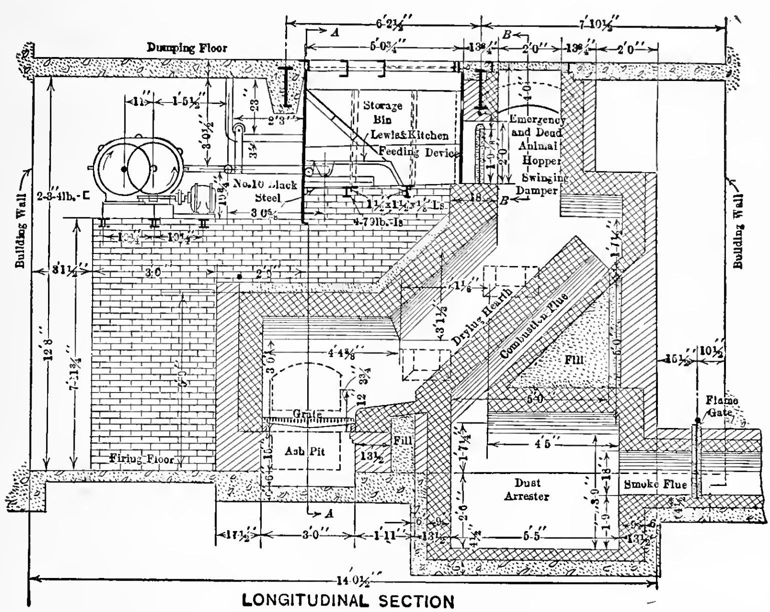


FIG. 88.—Lewis and Kitchen Garbage Furnace with Automatic Charging Device.

is the quantity of carbon in 1 lb. of garbage. The product, 2.67×0.05, is thus the weight of oxygen, in pounds, required to burn the carbon in the garbage. In the second line, 8.0 is the weight, in pounds, of oxygen required to burn 1 lb. of hydrogen to H_2O, and the figure 0.005 is the quantity of hydrogen in 1 lb. of garbage corrected by the equivalent as hydrogen of the quantity of oxygen in the garbage, thus $0.01 - \frac{0.04}{8} = 0.005$. In the third line, the first figure (2.56) is the weight, in pounds, of oxygen to burn 1 lb. of carbon to CO_2, the second figure (0.8) is the assumed quantity of carbon in 1 lb. of coal, and the third figure (0.2) is the quantity of coal (400 lb. per ton) required per pound of garbage.

As air contains 23% of oxygen, by weight, this means that 2.61 lb. of air are theoretically required to burn each pound of garbage and the 0.2 lb. of coal. As an excess of air, amounting to from 50 to 100%, is necessary, the actual quantities supplied will be from 3.9 to 5.2 lb. of air per pound of garbage (not mixed refuse). The volume occupied by this quantity of air depends on the temperature of the gases of combustion at the part of the furnace under consideration.

There are five methods of supplying air to the fire:

a. Natural or chimney draft; which is the utilization of the difference in weight between the warm products of combustion and the cooler and heavier outside air;
b. Forced draft produced by a steam jet set in or near the ashpit;
c. Forced draft by fans or blowers;
d. Induced draft by a steam jet or fan placed at the base of a chimney.
e. Combination of forced and induced draft.

a. Natural Draft.—Natural draft has the advantage of simplicity and ease of maintenance, as there are no moving parts needing repair, and there is a minimum of exposed parts. As the pressure of natural draft which can be provided economically is limited, and generally has not exceeded 1 in. of water in the ashpit, it is seldom used in refuse incinerators. With it, the pressure over the fire near the furnace door is generally less than atmospheric, and it is difficult to prevent the entrance of cold air from the outside. With forced draft, a slight excess of pressure can be maintained inside the furnace, so that no cold air can enter.

If the natural push up a chimney due to the heavier cold air outside is used to supply air to a number of units, the distribution of the draft through the furnaces is not easily controlled. Nevertheless, at present, it is likely that natural draft will be preferred for small

garbage furnaces, because of its simplicity and the fact that its cost is less than for artificial draft production. Natural draft is in fact the method used most frequently for supplying air to garbage furnaces.

The necessary height and cross-section of a chimney, to pass a given weight of air through a furnace in unit time, may be calculated by several formulas, but the results should always be checked by those of successful practice.

A rational theory of the action of the chimney was first worked out by Péclet and developed by Rankine. Based on these studies, Kent* offers the following formula, in which the constants, 7.64 and 7.95, refer to the densities of the outside air and the chimney gases, respectively:

$$H = \frac{P}{\frac{7.64}{T_a} - \frac{7.95}{T_c}}$$

in which H is the height of the chimney, in feet; P is the pressure in the ashpit, expressed as inches of water; T_a is the absolute temperature of the outside air; and T_c is the average absolute temperature of the chimney gases, both in degrees, Fahrenheit. Using this formula, a typical computation for a chimney for a garbage furnace is as follows:

1. *Assumptions:*

Temperature of air (T_a)	70° Fahr.
Temperature of chimney gases (T_c)	600° Fahr.
Rate of burning garbage	24 tons per day
Quantity of chimney gases per pound of garbage	5.0 lb.
Velocity of gases up chimney	10.0 ft. per sec.
Pressure of draft in ashpit (P)	0.5 in. of water
Weight per cubic foot of chimney gases	0.0394 lb.

2. *Height of Chimney:*

$$H = \frac{0.50}{\frac{7.64}{530} - \frac{7.95}{1060}} = 72.5 \text{ ft.}$$

3. *Cross-sectional Area of Chimney:*

$$\text{Area} = \frac{\text{Volume of gases}}{\text{Velocity}} = \frac{2000 \times 5}{0.0394} \times \frac{1}{3600} \times \frac{1}{10} = 7.1 \text{ sq. ft.}$$

The cross-sectional area of the chimney at the top is that of a circle with a diameter of 3.0 ft. As a general rule, the velocity of the up-draft should not exceed 10 ft. per second.

b. Forced Draft.—The advantages of forced draft depend on the character of the refuse. The more compact the refuse, the more dust

* "Mechanical Engineers' Pocket-Book, 7th Edition," p. 732.

and moisture it contains, and the more necessary it will be to force air through the mass, in order to supply sufficient oxygen for the required rapid combustion. A large proportion of fine ashes in the refuse, therefore, will demand a forced draft, when rubbish and garbage alone would not require it. In all cases, however, a forced draft will increase the temperature of combustion. All ironwork exposed to excessive heat, therefore, must be protected in some way.

Either fans or steam jets are used for artificial draft in practically all high-temperature refuse incinerators. There has been much discussion over the merits of these two methods. Present practice favors the fan draft, because of the tendency to get higher pressures in the ashpit. The various advantages and disadvantages of the two methods are summarized briefly below.

Steam jets use up more steam than fans. A steam jet will require from 10 to 15% of the total steam produced by the burning refuse; a fan will not require more than 10%, more often only 5%, of the steam. During the test of the Milwaukee incinerator, the power for fan engines, hoisting cranes, and electric lights required 8.3% of the total steam output.

Steam jets are cheaper than fans, are more easily arranged, require less attendance, and are less expensive to maintain. However, they are not as accessible for repairs, because they are generally placed in the ashpit of the furnace.

A steam jet cannot operate without steam, whereas a fan may be driven by an electric motor. In a small plant, where the quantity of steam is not always sufficient, this difference is important. A steam jet cannot be used economically to produce a high-pressure draft. Its ordinary working limit is a pressure of 3 in. of water in the ashpit. The steam passing through the grate with the draft from a steam jet prevents the clinker from adhering to the grate, which makes clinkering easier. This advantage, however, is not important with modern appliances for mechanical clinkering. The steam draft has a tendency to make the clinker more porous and friable, and thus less suitable for concrete and other useful purposes.

Maxwell* states that with steam jets "a steadier steam pressure is maintained and more steam per ton of refuse is available at the engines." On the other hand, Mr. J. A. Robertson, Chief Engineer of the Electricity Works and Refuse Destructors at Greenock, Scotland, favors the use of the fan draft. The effect of the steam in the draft has been well stated by Lord Kelvin and Professor Barr, after experiments at the Oldham destructor works, in the following extract from their report:

* "The Removal and Disposal of Town Refuse," by W. H. Maxwell, London, 1898.

"The steam is condensed by contact with the cold air which it injects, and the water thus produced is re-evaporated in contact with the furnace bars, keeping down their temperature. In this way the life of the furnace bars is greatly prolonged. A more important function is, however, fulfilled by the steam. In coming into contact with the incandescent fuel it is decomposed, the hydrogen being freed, while the oxygen combines with the carbon in the fuel to form carbon monoxide.

"This decomposition of the water is effected by heat abstracted from the lower part of the fire, where it can be of comparatively small value for the cremation of the distillate.

"The water gas (hydrogen and carbon monoxide) passes upwards to be burned by the excess air which it meets over the fire, thus serving to increase the temperature which would otherwise exist at the meeting of the products of combustion with the gases distilled from the raw material."

Tabulations have been compiled by Goodrich of tests made at refuse incinerators using both types of forced draft. He concludes that a greater quantity of CO_2 in the flue gases results from the steam-jet blast, and therefore indicates better combustion.

Many thorough tests have been made, also, with the fan blast. From these it seems probable that the use of high-draft pressures, giving higher burning efficiencies, will be preferred in the future, and, therefore, that fan draft will be used more generally on this account. With very dry combustible refuse, steam (possibly exhaust steam) let into the ashpits might tend to preserve the grates without affecting materially the other portions of the fire and furnace.

It is well to place the exhaust so that all fumes given off on the drying hearth will pass over the hot fire before entering the flue. The forced draft, with a tightly closed ashpit, should be equal to at least 1 in. of water column. In Hamburg the pressures vary from 2 to 4 in.

It is claimed that fan draft can be used to suppress dust in the building, by drawing the air supply for the fan from the firing and clinkering rooms. Obviously, by this method, some of the dust and smoke are drawn away from the operators and forced through the fire to the chimney. In actual practice, however, the effect is not great, because the quantity of air required for combustion is not large compared with the quantity naturally entering the building.

There is a variety of steam jets, fans, and blowers in the market. A section through the steam jet used in the incinerator at Westmount, is shown in Fig. 89. The engine-driven fan at the incinerator at West New Brighton, is shown in Fig. 90. Fans can be driven by steam engines, turbines, or electric motors. Steam turbines are used at Atlanta and Savannah.

c. Induced Draft.—Induced draft is not used frequently. After the incinerator at Atlanta went into operation, it was found that the chimney was not large enough to carry away the furnace gases. The draft, therefore, had to be increased. This was done by the use of a fan placed at the base of the chimney.

The combination of induced and forced draft incidentally increases the capability of the plant and the flexibility of the furnace to take care of refuse of different characteristics due to seasonal variations. This increased draft, however, increases the velocity through the chimney, so that provision must be made for preventing the escape of paper and dust at the chimney top. This can be done if paper and

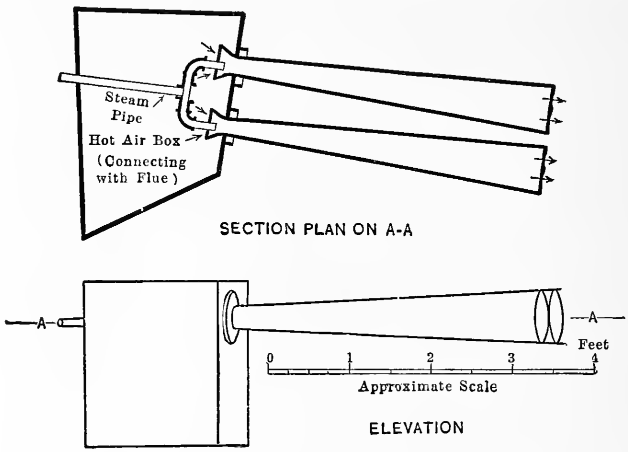


FIG. 89.—Steam-jet Blower, Westmount Incinerator.

A blower is placed in the ashpit beneath the grates in each division of the furnace cell.

dust are caught in the dust chambers before reaching the induced-draft fan.

d. Temperature.—Of great importance is the question of the temperature of the air as it enters the ashpits. In many small plants, particularly garbage furnaces, the air supplied is at the atmospheric temperature. In the larger modern incinerators, the air is pre-heated to temperatures as high as 400° Fahr. The advantage of a hot air supply for all combustion processes is now generally recognized, especially if the added temperature is obtained by heat which would otherwise be wasted and lost.

There are several special advantages in pre-heated air when burning refuse. If the refuse has a high content of moisture, a hot-air supply assists in its evaporation. Mixed refuse in America does

not ordinarily contain more than 20 or 25% of combustible. Air at a temperature of, say, 350° Fahr., occupies almost twice as much

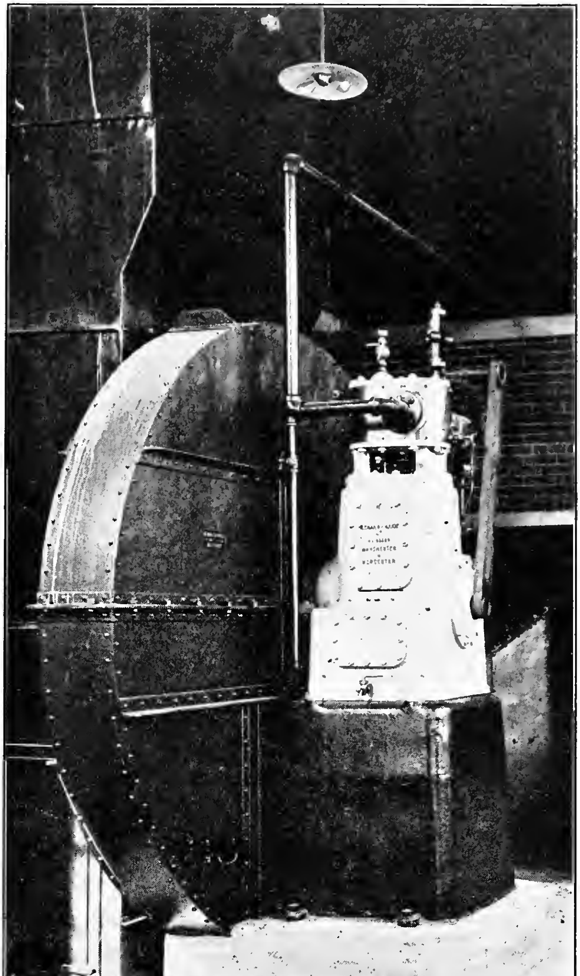


Fig. 90.—Electrically-driven Fan, West New Brighton Incinerator.

space as air at 70° Fahr. On this account it will saturate the mass of refuse more thoroughly, and supply oxygen to all the available combustible matter.

The air supply may be pre-heated by any of several methods, as follows:

A battery of tubes may be built into the outlets from the boiler or the main flue. The waste gases are passed through these tubes, and the air is forced around the outside and takes up heat on the way to the ashpit. Leask states that, in such a battery, the rate of transmission of heat from the gases to the air is about 1000 B.t.u. per hour per square foot of tube surface, and that in this way the temperature of the air can be raised about one-quarter of a degree for every square foot of heating surface. Temperatures as high as 400° Fahr. can be thus obtained.

Another arrangement is to drop the hot clinkers into a chamber below the ashpit and pass the air supply over this clinker on its way to the ashpit, as done at West New Brighton, Atlanta, and elsewhere. In these plants the main part of the pre-heating is done through a battery of tubes placed in the main flue. Heat is saved and retained for use in the furnace by thus abstracting it from the hot clinkers.

A third method of pre-heating the air, which has been used in many of the Horsfall plants, is by forcing it through cast-iron boxes forming the side-walls of the fire-grates. This not only pre-heats the air, but also keeps the cast-iron grate-curbs cool, and assists the process of clinkering. This method is used at the refuse incinerator at Greenock, Scotland. Mr. Robertson, Chief Engineer, reports, however, that he cannot pre-heat the air to more than 180° Fahr. He also states that

> "A further disadvantage is that, as the amount of heat then imparted to the air supply depends on the temperature of the furnace near the grate level, the temperature of the draft air is lowest immediately after charging, i.e., just at the time when high temperature is most needed to dry the refuse and to commence combustion."

These comments are obviously proper, and modern plants almost always have pre-heaters with special tubes beyond the boiler. The pre-heater at Milwaukee, set just at the outlet from the boiler, is shown in Fig. 91. It should be noted that the tubes through which the hot gases pass are set vertically above a large space into which the dust from the tubes can be blown out and removed. Some such arrangement is necessary, if the maximum rate of heating is to be maintained.

The value of pre-heating the air consists in reducing the volume of waste heat, promoting more efficient combustion, and increasing the temperature of the furnace, as will be shown in the " heat balances " given later.

The importance of pre-heating and properly proportioning the quantity of the air supply cannot be overestimated. An appreciable loss of efficiency is found both with a deficiency and with an excess of air.

e. Chimney.—In the actual construction of refuse incinerators and garbage furnaces, a chimney is always required to conduct the gases of

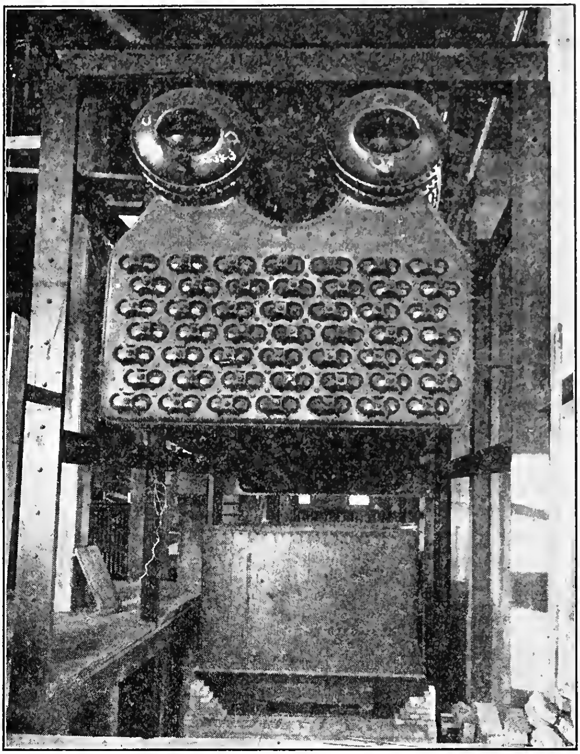


Fig. 91.—Boiler and Pre-heater, Milwaukee Incinerator.

combustion well above any neighboring buildings. Consequently, a certain natural draft is provided. This chimney must be of ample capacity to carry away the furnace gases without creating a back pressure, and it should be too large rather than too small. Therefore, in practice, a combination of forced draft and natural draft is used in refuse incinerators, and only natural draft in garbage furnaces. Table 108 shows the height, diameter, etc., of the chimneys in use at various plants.

TABLE 108.—HEIGHT, DIAMETER, AND CROSS-SECTIONAL AREA OF INCINERATOR CHIMNEYS

Location of plant	Rated capacity, in tons per 24 hours	Chimney				Type of draft
		Height, in feet	Diameter, in feet	Top internal cross-sectional area, in square feet	Area of cross-section per 10 tons of rated capacity, in square feet	
AMERICAN:						
West New Brighton....	120	136.5	7.5	23.7	1.98	Fan
Clifton, N. Y.........	90	134	....	19.6	2.16	"
Milwaukee, Wis.......	300	154	10	78.5	2.61	"
Seattle, Wash.........	60	80	6	29.1	4.8	Steam-jet blower
Atlanta, Ga..........	250	150	8.5	56.0	2.24	Double fan
Savannah, Ga.........	130	150	6.5	33.2	4.4	Fan
Paterson, N. J.........	60	150	6.5	33.2	5.5	Turbine blower
San Francisco, Cal.....	120	175	9	56.0	4.66	Fan
Montgomery, Ala......	60	100	4	12.6	2.1	Steam-jet blower
Vancouver, B. C......	50	120	....	......	......	Fan
Westmount, Que. (Meldrum).........	50	150	6	28.3	2.8	Steam-jet blower
Westmount (Heenan)..	No separate chimney.			Uses power plant chimney		
Halifax, N. S.........	50	115	6	28.3	5.7	
Toronto, Ont.........	180	175	7.5	......	......	Fans
Havana, Cuba........	500	150	11	95.0	1.9	Natural draft
ENGLISH:						
Hull Municipal Corp'n.	90	110	7.5	44.2	4.9	Steam-jet blower
Leamington Muncipal Corporation........	25	90	5	19.6	7.8	" "
Liversedge Urban District Council........	13	90	3.5	9.6	7.4	" "
Lowestoft Municipal Corporation........	28	120	6.5	33.2	11.9	" "
Colne.................	18	210	6	28.3	15.7	Fan
Lytham Urban District Council............	10	50	3.75	11.00	11.0	Steam-jet blower
Moss Side Urban District Council........	26	90	5	19.6	7.5	" "
Ramsgate Municipal Corporation........	26	120	5	19.6	7.5	" "
Southport............	40	180	7	38.5	9.6	" "
Stockton-on-Tees......	20	130	4	12.6	6.3	" "

At some garbage furnaces, half-burned paper has been carried out of the chimney by spurts in the irregular draft. This may be prevented by placing a coarse screen at the base of the chimney.

4. Flues and Furnace Accessories.—A study of the flues, combustion chamber, boilers, and chimney, requires a determination of the quantity of gases of combustion and of their temperature, in order to find the volume to be provided for. The weight of the volatile products or waste gases can be ascertained with sufficient accuracy by adding 0.75 lb. to the actual quantity of air supplied in the draft. To find the areas of flues, the quantity of air to be supplied may be taken at twice the theoretical quantity, to which should be added the 0.75 lb. of volatile products from the refuse.

The volume of steam that can be developed in a boiler is dependent on the calorific value of the refuse, the air supply, and the temperature of combustion. These elements of the design of a refuse incinerator can be studied advantageously by using a " Heat Balance."

The temperature of combustion and the probable evaporation in the boiler can be computed as follows: The mixed refuse is, for this purpose, assumed to have the following chemical composition, by weight:

Carbon	20%
Hydrogen	3%
Oxygen	6%
Nitrogen	4%
Ash, etc.	25%
Water	42%
Total	100%

Total available British thermal units per pound = 4296

Air required for combustion per pound of refuse = 3.1 lb.

At 100% excess, this is equal to .... 6.2 lb.

With these data, we may now make a heat balance, or an approximate distribution of the total British thermal units available from each pound of refuse burned.

Heat Balance

1. Heat required for the evaporation of 0.42 lb. of water, 966×0.42	= 406 B.t.u.
2. Superheating this steam 1200° Fahr., $1200 \times 0.35 \times 0.42$	= 176 B.t.u.
3. Loss due to unburned carbon in clinker and ash, $14{,}500 \times 0.05 \times 0.25$	= 182 B.t.u.
4. Heat lost in the hot clinker. Assume an average temperature throughout the mass of 500° Fahr. and a specific heat of 0.2; $500 \times 0.2 \times 0.25$	= 25 B.t.u.
5. Loss in radiation, 20%	= 857 B.t.u.
	1646 B.t.u.
6. Heat lost in dry chimney gases after leaving pre-heater, $6.2 \times 550° \times 0.264$	= 925 B.t.u.
7. Available for raising steam, calculated by difference	= 1725 B.t.u.
Total to balance	= 4296 B.t.u.

This heat balance, of course, is only approximate, and it would require several trials to obtain accuracy, as it is based on several indeterminate factors, but in practice one calculation will often suffice. The assumption that the steam will have to be superheated to 1200° may be corrected after computing the temperature of combustion, but the resulting change will not be great in proportion to the radiation losses.

Under these assumptions, the evaporation in the boiler, from and at 212° Fahr., will be,

$$\frac{1725}{966}=1.79 \text{ lb. of water per pound of refuse.}$$

For determining the temperature of combustion, the specific heat of the gases of combustion must be ascertained; this may be done as follows, assuming 100% excess of air:

Weight of Gases as Products of Combustion per Pound of Refuse.—

N:	$(3.1-0.714)\times 2.00+0.04$	$=4.87$ lb.
CO_2:	Since 12 lb. of C give 44 lb. of CO_2, we have $\frac{44}{12}\times 0.20$	$=0.73$ lb.
H_2O:	Since 1 lb. of H gives 9 lb. of H_2O, 0.03×9	$=0.27$ lb.
	In the fuel	$=0.42$ lb.
	16 lb. of O give 18 lb. of H_2O, we have $\frac{18}{16}\times 0.06$	$=0.07$ lb.
O:	In excess air	$=0.71$ lb.
	Total	$=7.07$ lb.

The specific heat of each of these products of combustion is known, so that their average specific heat can be calculated.

$$\begin{aligned}
N &= 0.244\times 4.87=1.19\\
CO_2 &= 0.22\ \times 0.73=0.16\\
H_2O &= 0.48\ \times 0.76=0.36\\
O &= 0.217\times 0.71=0.15\\
&\overline{\qquad\qquad\qquad 1.86}
\end{aligned}$$

=Heat required to raise 1 lb. of the products of combustion 1° Fahr.

$$\frac{1.86}{7.07}=0.264=\text{specific heat of products of combustion.}$$

The heat available for raising the temperature of the gases of combustion is equal to the sum of Items 6 and 7 in the heat balance, because all the other items represent heat lost, and not left in the products of combustion. These two items amount to 2650 B.t.u. The average temperature of combustion will then be

$$\frac{2650}{1.86}=1420° \text{ Fahr.}$$

In this computation, no separate account has been taken of a pre-heated air supply. The assumption is here made that the pre-heating process merely keeps a certain quantity of heat in the furnace and prevents a loss, but does not add to the actual available heat supply.

A pre-heated air supply is advantageous. In the first place it brings the air to the fuel in very much larger volume per unit weight. This means that the air supply permeates the refuse more thoroughly, and the oxygen in the air searches out the carbon and hydrogen in the refuse more completely. Furthermore, the heat brought to the furnace at this point assists in driving off the excess moisture of the refuse, thus facilitating combustion. These items are in addition to the saving of heat that would otherwise be lost at the chimney.

Mr. Fetherston prepared a heat balance for the mixed refuse incinerated at West New Brighton in 1907. Table 109 gives the results of his investigation.

TABLE 109.—APPROXIMATE HEAT BALANCE PER POUND OF MIXED REFUSE

(From paper by J. T. Fetherston, *Transactions*, Am. Soc. C. E., Vol. LX, 1908)
Heat values in British thermal units. Estimated temperatures

	Spring	Summer	Autumn	Winter	Year	Sept.*
Calorific power of refuse	4747	3477	3833	4358	4274	3265
Losses due to:						
Moisture	184	373	363	174	259	465
Heat in dry chimney gases	465	407	421	443	444	395
Unburned carbon in clinker	266	229	232	306	252	229
Unburned carbon in ashes	324	380	268	468	332	380
Heat in clinker	55	38	44	63	54	54
Forced draft	121	106	110	115	116	103
Radiation, etc	949	695	767	872	855	653
Total losses	2364	2228	2205	2441	2312	2279
Net useful heat to boiler	2383	1249	1628	1917	1962	986
Equivalent evaporation, from and at 212° Fahr. (useful steam), in pounds of water per pound of mixed refuse	2.46	1.29	1.68	1.98	2.03	1.02
Estimated temperature in combustion chamber, in degrees, Fahr	2370°	1710°	1950°	2140°	2150°	1550°
Moisture	14.03%	28.86%	27.74%	13.11%	19.74%	35.83%
Ash	50.06	39.74	39.74	52.72	46.03	33.69
Combustible	35.91	31.40	32.52	34.17	34.23	30.48

* Average calorific values for summer components were used in arriving at September results.

Flues.—The proper area of flues may be ascertained by proportioning the temperatures of the gases from the 1420° Fahr. at the fire to the assumed 550° in the chimney. The weight of the gases as products of combustion was found to be 7.07 lb. per pound of refuse.

The volume occupied by the total weight of gases at the computed temperature can be determined by reference to Table 93.

Combustion Chamber.—A combustion chamber is usually inserted between the grates and the boiler or chimney. It serves to equalize and steady the temperature from different grates as well as to afford time for complete combustion before the furnace gases reach the comparatively cold surfaces of the boiler tubes or chimney walls. It also serves as a pocket for catching dust.

A consideration of the combustion chamber and the boiler involves, not only the estimation of the available heat units and the temperature of combustion, but also the question of dust. When burning mixed refuse under a forced draft, we find that a considerable volume of ash dust is carried away from the fire into the combustion chamber and flues.

For removing dust from flue gases two methods have been used. The first, and the one most usually applied, depends on the principle of sedimentation by a reduction in the velocity of the flue gases below the suspension point. This is done by enlarging the section of the flue through the combustion chamber. Then a large number of dust particles will settle out. Storage for the dust thus collected must be provided.

At the Milwaukee incinerator, the grates are set on each side of a common combustion chamber. The gases enter the latter from opposite sides, and so tend to check their own velocity. Besides, the velocity is further reduced by an enlargement of the chamber. To receive the settling dust, there is a pit, about 6 ft. deep, below the combustion chamber proper, from which the dust is removed by hand.

Even with these devices, some dust passes along and settles on the boiler tubes. Therefore, provision must also be made for blowing it out into a storage space below, so that the efficiency of the boilers may not be seriously reduced. At Milwaukee it was necessary to remove dust from the combustion chamber pit and boiler pit at intervals of from two weeks to one month. The main flue from the boilers to the stack was cleaned twice a year.

The other method of dust removal is by utilizing centrifugal force. At the base of the chimney the gases are carried at the usual high velocity around a circular duct. Centrifugal force throws the dust particles to the circumference, where they collect in pockets from which they can be removed. This method has been used in England, but not extensively. It is open to the objection that no dust is removed from the gases before they enter the boiler.

In some incinerators, especially in Germany, the combustion chamber, in serving also as a dust chamber, is set high and provided

with sloping hopper bottoms. The dust can then be removed into cars through a sliding door at the bottom. This arrangement is illustrated in Fig. 83.

The location, size, and shape of the combustion chamber, with relation to the boiler, is important. The shape must insure a proper mixing of the gases. The boiler must not be so close to the grates that the gases of combustion will be cooled before complete combustion has taken place. The length of time required for the combustion obviously depends on the character of the refuse. With a refuse high in volatile matter, or of low calorific value, the distance to the boiler must be greater than would be required for a highly combustible refuse. At a number of successful plants, and with average refuse, the boiler entrance is set about 10 ft. from the grates. The value of steam, the character of the neighborhood, and the topography near the plant, should also be given consideration.

In garbage furnaces, the combustion chamber has often been omitted, and in some cases it has been placed so far from the grate proper that it is of little value. This occurs when long garbage hearths for drying are set between the coal grate and the outlet of the furnace. In some few plants, the drying hearths are built in small units, with small combustion chambers following each hearth.

5. Clinker and Ash Handling.—In burning mixed refuse, clinker and ash remain after the combustion. The clinker is a hard, vitreous mass, often glowing, and may cover the whole grate to a depth of as much as 10 in. If the clinker door is wide enough, the clinker mass can be removed as one body from the grate. If the door is narrower than the grate, the mass must be broken up before it can be removed. Under and around the clinker there is much fine and coarse ash. Some of this falls into the ashpit, some is withdrawn with the clinker, and some should be left on the grate to ignite the next charge of refuse.

"Clinkering" is the process of removing clinker. It requires both strength and skill. To promote furnace efficiency, clinkering must be done quickly, in order to reduce to a minimum the inrush of cold air. The draft should be shut off during the interval and put on a few minutes before re-charging. Quick clinkering also reduces the time when a grate is out of service.

During the test of the Milwaukee incinerator, where clinkering was done by hand, the average time required for one grate was about eight minutes. With mechanical clinkering, as at Atlanta, the material can be removed from the grate in less than one minute. After clinkering, live fires should be left on top, and evenly spread out to ignite the new charge.

Garbage alone, burned with coal, produces very little clinker, but mostly fine ash, which can be handled with shovel and wheelbarrow.

Marked improvements in apparatus for handling clinker and ash have been developed during the past few years, largely by American engineers. In the earlier designs, clinker was removed from the grate by hand with slice-bars, rakes, and hoes, and placed in small cars. A good deal of it was spilled on the floor and had to be shoveled into the cars. This process was also laborious.

The first improvement was to get the clinker automatically into the clinker car for delivery to the dump or crusher. The firing floor was built high enough to afford a good basement, and a trap door was set into it just in front of the clinker door. The hot clinker could thus be dropped from the grate through the trap door into the car below.

At West New Brighton, and elsewhere, the clinker falls into a clinker cooling chamber under the ashpit, from which it can be discharged by gravity into cars.

Subsequent improvements related to the withdrawal of the clinker from the fire. This is now accomplished successfully by mechanical appliances, so that the labor and time of clinkering is reduced to a minimum. Two general types of apparatus are in use:

1. The "pull" method, as developed at Frankfort, Germany, and also used at Savannah; and
2. The "push" method, as developed at West New Brighton, and also used at Paterson, Clifton, and Atlanta.

The method in use at Frankfort requires the construction of a furnace door of the same width as the grate. When the fire is building up, and before the clinker is formed, a zigzag iron bar is set into the refuse, about 6 in. above the grate, and is fused into the clinker. The bar has a ring or handle at the outer end. Just before clinkering, a clinker car, opening at the grate level, is placed in front of the clinkering door. Then this door is opened and a chain from a traveling winch is hooked to the handle of the bar, and, by the winch, the clinker is pulled bodily out of the grate into the clinker car. The bar is then recovered from the clinker and used for the next charge.

A similar clinkering device is used at Savannah, where the clinker is pulled out by hydraulically-operated cylinders, instead of by a winch. This method requires a hard clinker, or the bar will not take hold but pull out. The clinker bar at Savannah is made like a hoe; the clinker is rather soft, yet there is but little ash. The bars burn out quite frequently. A section of the Savannah incinerator is shown in Fig. 100.

The "push" method of clinkering was devised at West New Brighton. Two hydraulically-operated groups of cylinders are used.

The upper ones are fastened to the movable grates of the furnace. The grates have ridged bars bent up at the inner end. They are pulled out from under the clinker, and, in passing, the bars break it up. The hot clinkers fall into a cooling chamber below the grate, which may have sufficient capacity for several charges. The lower hydraulic cylinders are connected with heavy cast-iron pushers. These push the clinker out of the cooling chamber into the clinker car. A section of the Atlanta incinerator, where this method is used, is shown in Fig. 92.

6. Dust.—An important and annoying feature in refuse incineration is the dust about the plant during operation. Dust comes from the dumping of the collection wagons, the charging and clinkering of the fires, and the disposal of the clinker. It varies in quantity with the character of the refuse, type of plant, and care of operation. Refuse containing greater quantities of ash will produce correspondingly more dust, particularly on warm and windy days, and, in some cases, in order to keep it down, it is necessary to dampen the stored refuse. Plants operating with high-pressure draft make more dust than others (see C. 2. Hamburg), and the conditions are aggravated if the flues and chimney have not been proportioned correctly. A naturally somewhat dirty condition is still further increased by slovenly and unclean operation. In garbage furnaces, where garbage is burned without ashes, and under natural draft, the dust problem is not a serious one.

Thus far, only two precautions have been taken against this nuisance. One quite effective remedy is a liberal use of water on the stored refuse and on the hot clinker and ashes about the building. The other consists in withdrawing the dusty air from the building by the suction of the forced-draft apparatus. This is a usual procedure, and is commendable because it secures some advantages which otherwise would be lost. In a large building, however, with many windows, doors, and other openings, unless these are temporarily closed, the desired effect is considerably reduced by large volumes of fresh air entering and other air leaving the building.

7. Ventilation.—The ventilation of the building is, of course, associated closely with the dust problem, but should be considered primarily with reference to the workmen operating the plant. Their efficiency and comfort require sufficient fresh and clean air and a chance to be protected from the great heat of the furnace. Plenty of doors and windows, affording access to the outside air, and openings for fresh air to enter, may serve the purpose of ventilation as well as a mechanical plant. It is advisable to provide for ventilation also through the roof. Most of the air in an incinerator building is warm,

and rises. If there are ventilators in the roof, the hot air escapes through them and fresh cool air enters below. At Milwaukee, where the incinerator building covers about 10,000 sq. ft., and contains four 75-ton furnaces, six 18-in. ventilators have now been built in the roof. In the original contract only two were included; the others were built after experience in operation had shown that they were advisable.

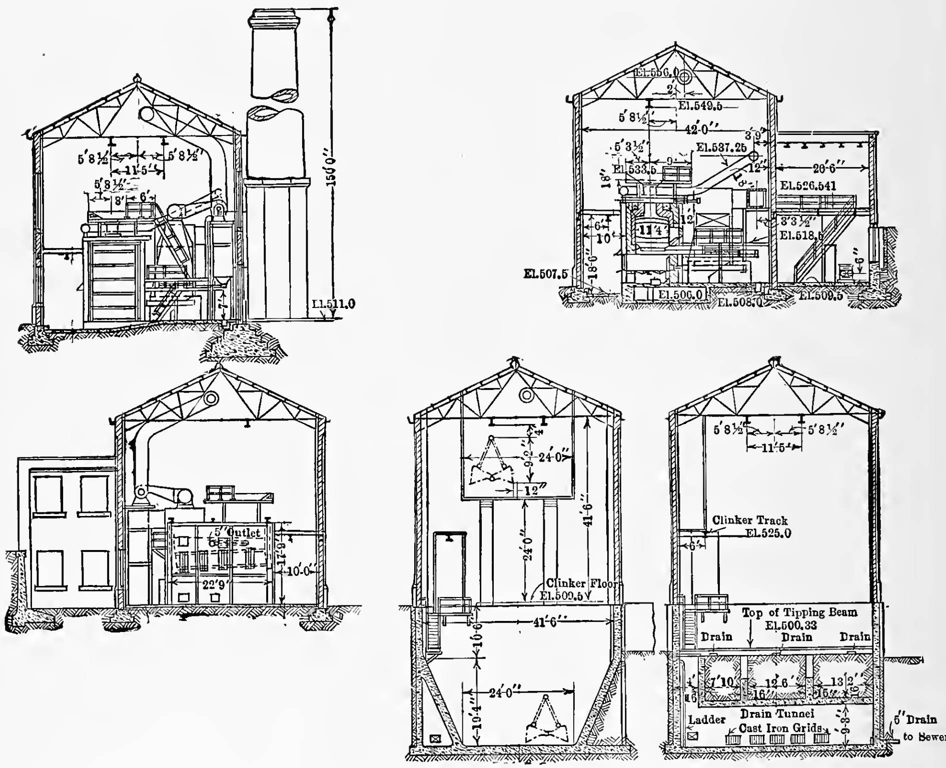


FIG. 92.—General Sectional Arrangement of Atlanta Incinerator.

Although odors at reduction works result chiefly from the processes of reducing, those of incinerating plants are due to unskillful operation. The material, in the latter case, when delivered promptly as mixed refuse, has less odor than garabge alone, yet it should be burned as promptly as possible. The operation of the furnace, including attention to proper drafts, and, especially, attempts to burn wet garbage without a sufficient quantity of combustible rubbish,

requires skill and attention. The furnaces should be fed so as to create continuously a high temperature, say, at least 1250°, as this should prevent any possible escape of odorous gases from the chimneys.

Some of the odors, for the removal of which ventilation is necessary, arise from the adhesion of fine particles of partly burned organic matter to the interior walls and to surfaces of apparatus, and to clothing, and these odors persist for some time. The most effective way of removing them is by air washing, that is, by playing a jet of compressed air on the surfaces. General cleanliness should be observed about the works.

D. TESTS

During the last few years a number of tests of refuse incinerators have been made, the results of which have been published in America, in England, and in Germany. These tests give much useful information relative to the principles and practice of incineration, and, taken consecutively, mark the progress that has been made in the art.

When studying the results of official tests, it should be remembered that at such times specially favorable conditions generally prevail. The men operating the fires are keyed up to a working rate sometimes much above normal. All parts of the plant are watched by faithful and skilled attendants, and the result is frequently above the standard of everyday operation. The readings and measurements made during tests, however, are generally accurate, and the resulting computed figures may be used as an indication of a practicable high rate of operation attainable under the best conditions. The longer the duration of the test, the more nearly will the results approach those of average conditions of operation. Summaries of the tests of the incinerators in a number of American cities are given in Table 110. This will serve for purposes of comparison. The order is progressive, and indicates plainly the improvement in the quantity of refuse which can be incinerated per square foot of grate area.

The first complete modern test made on this side of the Atlantic was at **Westmount.** A description of the same is given in *Engineering News* of May 24, 1906. It was found that our mixed refuse was well suited for incineration, as 1 lb. evaporated 1.36 lb. of water, from and at 212° Fahr. This gave encouragement to the introduction of high-temperature incinerators in America. Table 111 gives a summary of this test.

Two years later a test was made at West New Brighton of the first large high-temperature refuse incinerator in the United States. It was built by the Power Specialty Company, of New York. The results of the test showed that 1 lb. of mixed refuse evaporated 1.21 lb. of

TABLE 110.—SUMMARY OF

Plant	Date of test	Kind of incinerator	Composition of Refuse. Garbage	Composition of Refuse. Fine ash	Composition of Refuse. Coal and cinders
Westmount, Que...	May 3, 1906	Meldrum. Top-feed.	15.	65.	
West New Brighton.	May 6, 1908	Heenan and Froude. Back-feed.	46.6	21.7	8.3
" "	May 8, 1908	do.	11.8	79.5	
" "	Jan. 1 to Dec. 31, 1911	do.	24.9	68.	
Seattle, Wash.....	Mar., 1908, to Jan., 1909	Meldrum. Front-feed.	23.8	43.6	
Milwaukee, Wis...	May 19–20, 1910	Heenan. Top-feed	56.7	30.6	
" " ...	May 23–24, June 3, 1910	" "	29.7	59.7	
" " ...	May 26 to June 1, 1910	" "	40.8	41.0	
Savannah, Ga.....	Aug. 21–22, 1914	Heenan	45.0	10	
Clifton, N. Y......	July 24, 1913	"	48.6	14.2	8.4
" "	July 29, 1913	"	22.0	39.1	23.0
" "	Aug. 13, 1913	"	52.3	14.2	8.0
" "	Aug. 15, 1913	"	24.3	39.0	22.7
Halifax, N. S......	Mar. 8, 1913	Sterling	16	75	
Paterson, N. J.....	Dec. 1–6, 1913	Heenan	8	78	
" "	Dec. 15–16, 1913	"	12	72	
San Francisco, Cal.	Sept. 4 to Oct. 3, 1914	"	*	.....	......
Berkeley, Cal......	Jan. 10–31, 1914	Sterling	.....	.....	.....
" "	Feb. 2–7, 1914	"	.....	.....	.....
Atlanta, Ga.......	Aug. 8, 1914	Heenan	48.5	16.6	
Ridgewood, N. Y..	May 8, 1916	Decarie	70.9	.....	.....
" " ...	May 10, 1916	"	70.3	.....	.....
" " ...	May 15, 1916	"	70.1	.....	.....

* See Table 117.

water, from and at 212° Fahr. Table 112 gives the details of the test. The plant is described in *Engineering Record,* October 3, 1908.

In 1910 a test was made of the incinerator at **Milwaukee.** This was the largest plant of its kind, its capacity being 300 tons per day. It was also built by the Power Specialty Company. The results of three tests showed that 1 lb. of mixed refuse evaporated 0.96, 1.34, and 1.45 lb. of water, respectively, from and at 212° Fahr. Table 113 gives the details. A description of the tests follows:

SEVERAL TESTS OF INCINERATORS

Percentage by Weight			Pounds of refuse burned per square foot of grate surface per hour	Evaporation. Pounds of water evaporated per pound of refuse, from and at 212° Fahr.	Number of Table giving details	Authority
Glass and metals	Rubbish	Manure				
5.0	15	.....	58.7	1.36	111	*Engineering News*
8.5	14.9	.....	52	1.41	112	*Engineering Record*
3.4	5.3	.....	49.7	1.25	112	" "
7.1		.....	....	....	112	
20.4		12.2	54.8	....	....	*Engineering News*
5.9		6.8	63	0.96	113	" "
6.8		3.8	65	1.45	113	" "
4.8		13.4	64	1.34	113	" "
40.0		5	80.6	1.62	116	*Munic. Eng.*, Dec., 1914
1.2	10.5	17.1	143.3	....	115	J. T. Fetherston
2.8	4.8	7.9	139.0	....	115	"
1.0	8.5	16.0	147.2	....	115	"
2.7	3.9	7.4	147.2	....	115	"
9		.....	77.7	....	....	
14.0		.....	100	....	....	H. de B. Parsons
16.0		.....	100	....	....	" "
.....	.....	.....	102-111	1.26	117,118,119	Power Specialty Company
.....	.....	.....	71	0.60	120	
.....	.....	.....	77	1.01	120	
34.9		.....	129	1.72	121	Power Specialty Company
.....	29.1	.....	69.7	....	122	*Engineering News*
.....	29.7	.....	72.4	....	122	" "
.....	29.9	.....	64.1	....	122	" "

Records of the temperature and evaporation were taken regularly throughout all the tests. Temperatures in the combustion chamber were taken every fifteen minutes with a Bristol electric pyrometer, calibrated to read to 2400° Fahr. The points of the instrument extended through the sight hole in the door of the combustion chamber, and about 5 ft. into it, and therefore not into the hottest part. All other readings were taken every half hour. The Bristol pyrometer was checked against three other high-temperature recorders, and

TABLE 111.—SUMMARY OF TEST OF WESTMOUNT REFUSE INCINERATOR, 1906

Duration of test	8 hrs. 32 min.
Number of cells	3
Total grate area	75 sq. ft.
B. & W. boiler heating surface	2,197 sq. ft.
Refuse consumed (composition of waste material):	
Garbage, manure, and leaves	15%
Ashes and unburned (anthracite) coal, cinders, etc	65%
Iron, wood, bottles, tins, leather, etc	5%
Rubbish, including paper, branches, old furniture, etc	15%
Total	100%
WEIGHTS:	
Unscreened refuse, rubbish, garbage, manure, etc	38,090 lb.
Tins, etc., not burned	540 "
Net quantities consumed	37,550 "
Refuse consumed per hour	4,402 "
Refuse consumed per hour per square foot of grate area	58.7 lb.
Weight of clinker remaining after combustion	15,880 lb.
Percentage of clinker and ashes to refuse consumed	42.1%
WATER EVAPORATION:	
Total water evaporated	41,991 lb.
Water evaporated per hour, actual	4,920 "
Water evaporated per hour, from and at 212° Fahr	5,970 "
Water evaporated per pound of refuse, actual	1.12 lb.
Water evaporated per pound of refuse, from and at 212° Fahr.	1.36 "
Water evaporated per pound of refuse, from and at 212° Fahr. and per square foot of total heating surface per hour.	2.72 "
PRESSURES AND TEMPERATURES:	
Temperature of outside air, average	55° Fahr.
Barometric pressure, average	29.5 in.
Average steam pressure	123.5 lb. per sq. in.
Average pressure in ashpits	1.74 in.
Average vacuum at chimney base	$\frac{9}{16}$ "
Average temperature of combustion chamber (by Watkin's heat recorders) over	1,994° Fahr.
Highest temperature of combustion chamber over	2,318° "
Lowest temperature in combustion chamber	1,742° "
Average temperature of air entering regenerator	75° "
Average temperature of air leaving regenerator	206° "
Average temperature of gases entering regenerator	427.5° Fahr.
Average temperature of gases leaving regenerator	337.5° "
Average temperature of feed-water	47° Fahr.
GAS ANALYSES:	
Percentage of CO_2 (average of six readings)	10.9%
Percentage of CO_2, highest reading	13.6%
Percentage of CO_2, lowest reading (clinkering fires)	4.5%
TIMES:	
Time taken to clinker one grate	10½ min.
Time between clinkerings	2 hr. 48 min.
Times each fire was clinkered	3

TABLE 112.—SUMMARY OF TESTS OF WEST NEW BRIGHTON REFUSE INCINERATOR

Test No.	1	2	3	4	5
Date, 1908	May 6	May 8	May 13	May 15	May 16
Duration, hours	8	6½	8	5½	8
Material (see note at foot of table)	Sept. mixture	Refuse as collected	Feb. mixture	Refuse as collected	Refuse as collected
Refuse burned, total tons	20.802	16.145	19.827	17.235	23.673
Refuse burned per square foot of grate area, hourly, lb.	52	49.7	49.6	62.7	59.2
Residuals:					
Clinker, lb.	10,930	8,390	11,466	12,965	17,344
Ashes, lb.	787	787	1,978	669	913
Tins, etc., not fired, lb.	1,046	340	448	389	349
Total, lb.	13,189	9,843	14,293	14,372	19,083
Percentage of original refuse	30.9	30.2	35.6	41.2	40
Evaporation per pound of refuse burned:					
Gross actual, lb.	1.17	1.03	1.10	0.91	1
Gross equivalent, from and at 212°, lb	1.41	1.25	1.33	1.10	1.21
Net useful steam for power purposes, from and at 212°, lb.	1.31	1.16	1.24	1.02	1.12
Carbon dioxide:					
Average, per cent.	12.2	12.3	12.5	12.4	12.9
Maximum, per cent.	17	16.5	17	17.6	16.3
Minimum, per cent.	6	8	6	8.6	7.6
Temperature in combustion chamber, deg. F.					
Average	1,846	1,715	1,637	1,698	1,792
Maximum	2,210	1,922	1,940	1,904	1,940
Minimum	1,526	1,526	1,382	1,526	1,634
Temp of chimney gases, deg.F.	393	380	364	397	......
Temp. of outside air, deg. F.	48.5	51.5	83.9	50.6	......
Temp. of air leaving heater, deg. F.	306	287	268	288	......
Temp. of feed-water, deg. F.	55	55	56	54	54
Average steam pressure, lb. per sq. in.	137.4	133.2	130.5	136.4	137.4
Number of fires clinkered	9	8	10	7	5
Average time per clinkering, minutes	9	8.4	11.9	12.3	8.2

Note.—The material burned during the different tests was as follows:

Test 1.—This "September mixture" was prepared artificially, and was made up of 46.6% of garbage, 21.7% of fine ash, 7.7% of coal and clinkers, 0.6% of clinker, 8.5% of glass and metals, and 14.9% of rubbish.

Test 2.—The material was refuse just as collected, and wet from the rain. A sample dried gave 38% of moisture.

Test 3.—This "February mixture" was prepared artificially, and was made up of 79.5% of ashes, 11.8% of garbage, 5.3% of rubbish, and 3.4% of glass and metals.

Test 4.—The material was refuse just as collected, and was wet from a rain of the previous day.

Test 5.—The material was relatively dry refuse as collected, and was representative material.

TABLE 113.—SUMMARY OF TESTS OF MILWAUKEE REFUSE INCINERATOR, MAY AND JUNE, 1910

(From *Engineering News*, July 21, 1910.)

Date	May 19 and 20	May 23, 24, and June 3	May 26 to June 1
Duration, in hours	37	36 hr. 26 min.	37
Grade of refuse tested	Extreme summer	Extreme winter	Average annual
Refuse burned, total tons	123.62	126.87	126.81
Percentage of garbage	56.7	29.7	40.8
Percentage of ashes	30.6	59.7	41.0
Percentage of rubbish	5.9	6.8	4.8
Percentage of manure	6.8	3.8	13.4
Rate of burning, in tons per 24 hours	80	84	86
Pounds per square foot of grate area per hour	63	65	64
Number of fires clinkered	57	62	63
Average time per clinkering, in minutes	7.8	9	7.3
Evaporation per pound of refuse:			
Gross actual, in pounds	0.79	1.19	1.10
Equivalent, from and at 212° Fahr., in pounds	0.96	1.45	1.34
Net useful, from and at 212° Fahr., in pounds	0.87	1.36	1.25
Temperature of feed-water, in degrees Fahr.	52	49	49
Average steam pressure, in pounds per square inch	146	133	130
Carbon dioxide:			
Average, percentage	9.3	8.8	12.9
Maximum, percentage	16.0	19.8	17.2
Minimum, percentage	6.2	5.5	3.5
Temperature, in degrees Fahr.			
Combustion chamber, aver'ge	1607	1668	1664
Combustion chamber, min'm	1267	1240	1267
Combustion chamber, maxi'm	1880	2060	2000
Chimney gases	581	597	515
Forced draft, leaving heater	398	358	351
Pressure of draft leaving heater, in inches of water	4.2	4.9	4.6
Furnace units under test	No. 4	Nos. 1 and 2	No. 1

was found to be approximately correct. The laborers employed during the tests were not skilled in this kind of work. The firemen had been working about one month on the furnaces before the tests were started, and had not had any previous experience in high-temperature firing. The water fed to the boilers was measured through a hot-water meter, calibrated by running a known weight of water through it. In some instances all the water delivered to the boilers was preferably weighed or measured.

At this plant an interesting test of steam production was made under working conditions from June 4 to 11, 1911, covering a period of six days of routine operation. A water meter on the main boiler feed line was calibrated, and read at frequent intervals, day and night. The quantity of each kind of refuse burned was recorded daily. The firemen worked the furnaces carefully, and no extra or special men were employed. The test was planned to determine the quantity and rate of steam production which could be secured under ordinary conditions of operation.

The test showed that the average quantity of water evaporated in the boilers was 19,200 lb. per hour; the maximum, 31,600 lb.; and the minimum, 8,800 lb. The average rate of evaporation, in pounds of water per pound of refuse, was 1.18; the maximum, 1.94; and the minimum, 0.54.

The following tabulation shows the quantities of refuse burned:

	Average tons daily	Average tons per furnace	Percentage by weight
Garbage	119.2	42.1	61.3
Ashes	48.3	17.4	24.7
Rubbish	19.3	7.0	9.8
Manure	4.7	1.7	2.4
Screenings	3.5	1.3	1.8
Totals	195.0	69.5	100.0

An exceptionally valuable record of plant operation was made in 1910 at the refuse incinerator at **Seattle,** which had a capacity of 60 tons per twenty-four hours, and had a front-fed and hand-fired furnace. It is given in Table 114.

Unfortunately, reliable tests of garbage furnaces, from the thermal point of view, have rarely been made. The principal data of a test of the furnace at **Racine** (population about 45,000), on December 13, 1913, are therefore of interest. This plant was designed by Mr. S. R. Lewis. The chimney is 150 ft. high and 4 ft. in diameter. There are

two furnaces, each having two units. The guaranteed capacity was 1 ton per hour in each of the units. The test was made on one furnace. The material to be burned (which was stored for several days in order to obtain the requisite quantity, namely, 8 tons) was composed of kitchen garbage and manure, with some general rubbish; this had an average weight of 31 lb. per cubic foot, and was frozen.

TABLE 114.—RESULTS OF OPERATION OF REFUSE INCINERATOR AT SEATTLE, 1910

Month	No. of days operation	Refuse burned, in tons	Clinker, in tons	Ash and clinker from combustion chamber and flues, in tons	Average daily quantity of refuse burned, in tons	Average time to clinker each fire, in minutes	Average time each fire was burning, in hours
Jan.	26	1811.022	945.720	57.000	69.655	13.85	3.70
Feb.	24	1549.212	843.470	48.100	66.426	13.10	3.18
Mar.	27	1814.944	953.801	47.600	67.220	13.37	3.16
April	26	1745.884	908.570	68.700	67.149	13.25	3.16
May	26	1794.643	751.300	50.100	69.025	11.50	3.10
June	26	1813.368	730.810	29.100	69.745	10.40	3.48
July	26	1764.751	561.540	22.960	67.875	8.72	3.57
Aug.	27	1892.631	594.330	21.161	70.100	9.15	3.43
Sept.	26	1861.782	660.775	23.150	71.607	10.35	3.33
Oct.	21	1560.925	655.910	20.175	74.330	10.92	2.82
Nov.	26	1919.054	884.110	38.710	73.810	10.45	2.38
Dec.	27	1954.856	1018.105	52.360	72.402	10.95	2.22

The fires were started at about 10 A.M. Three hours and 500 lb. of coal were allowed to heat the furnace prior to the test, which was started at 1 P.M. The refuse was introduced through the air lock at a fairly constant speed until 3:45 P.M., at which time the 8 tons had all been thrown in. In $1\frac{1}{4}$ hours, from 3:45 to 5 P.M., the material on the hearths was burned up completely.

From 2:50 to 3 P.M. the doors leading into the storage bins were purposely opened, rendering the air locks inoperative, and causing a drop in temperature to 900° at that time.

The quantity of coal burned per ton of refuse was 132 lb. The maximum quantity of coal guaranteed for 1200° temperature was 150 lb. The quantity of refuse burned per hour per square foot of grate area was 85 lb.

The temperature in the combustion chamber ranged from 1100° to 1475° (except for the short time when it was allowed to drop to 900°), the average being 1241°. The draft varied from 0.60 to 0.75 in.

TABLE 115.—WORK ELEMENTS OBTAINED DURING TESTS AT THE CLIFTON, N. Y., INCINERATOR, FOR ONE 45-TON FURNACE

From *Engineering Record*, June 20, 1914

Work elements	Summer mixture. North furnace, July 24, 1913	Winter mixture. North furnace, July 29, 1913.	Summer mixture. South furnace, August 13, 1913	Winter mixture. South furnace, August 15, 1913	Totals and averages
Duration of test, in hours	7	8	$7\frac{1}{2}$	8	30 hr. 34 min.
Weight of material, in pounds	46,350	51,367	51,450	54,420	203,587
Cost of incineration	$9.69	$10.695	$10.415	$10.875	$41.675
Cost per ton	$0.418	$0.417	$0.405	$0.400	$0.4094
Pounds burned per hour	6,621	6,421	6,800	6,802	6,660
Pounds burned per square foot of grate per hour	143.3	139.0	147.2	147.2	144.2
Weight of clinker, in pounds	12,615	20,995	13,680	23,125	70,415
Percentage of clinker to raw material	27.2	$40\frac{7}{8}$	$26\frac{1}{2}$	$42\frac{1}{2}$	34.6
Number of pan charges	61	50	66	59	236
Average weight per charge, in pounds	760	1,027	780	922	863
Average time to load pan (2 men part time)	4 min, 56 sec.	4 min. 59 sec.	4 min. 11 sec.	3 min. 34 sec.	4 min. 23 sec.
Average time of one man to load	7 min. 28 sec.	9 min. 58 sec.	5 min. 28 sec.	5 min. 30 sec.	6 min. 56 sec.
Average time per charge to grate	27.5 sec.	20.6 sec.	23.0 sec.	23.1 sec.	23.7 sec.
Total time charging to grate	27 min. 59 sec.	17 min. 10 sec.	25 min. 17 sec.	22 min. 40 sec.	1 hr. 33 min. 6 sec.
Percentage of time when furnace doors were open	6.6	3.6	5.7	4.8	5.1
Number of fires clinkered	$15\frac{1}{4}$	$16\frac{2}{3}$	18	21	$70\frac{11}{12}$
Average clinker per fire, in pounds	827.2	1,259.7	760.0	1,101.2	992.9
Average time to clinker	58.7 sec.	3 min. 9 sec.	57 3 sec.	59 7 sec.	1 min. 31.2 sec.
Time of removing clinker from cooling chambers per fire	1 min. 38 sec.	1 min. 25 sec.	1 min. 21 sec.	1 min. 25 sec.	1 min. 27 sec.
Time to cool clinker with water, per fire	4 min. 3 sec.	22 min. 39 sec.	8 min. 19 sec.	17 min. 48 sec.	13 min. 44 sec.
Time to crush clinker per fire	9 min. 30 sec.	11 min. 51 sec.	5 min. 51 sec.	10 min. 8 sec.	9 min. 19 sec.

TABLE 116.—RESULTS OF TEST OF HEENAN INCINERATOR AT SAVANNAH, AUGUST 21 AND 22, 1914

Duration of test: 3 A.M., 21st, to 12.30 A.M., 22d: 21½ hours.
Composition of refuse: Garbage 45%, rubbish 40%, manure 5%, ash 10%.
Type of incinerator: Two four-trough grate furnaces with forced draft.
Number of furnaces at work: 2.
Total grate surface: Both furnaces, 160 sq. ft.
Type of boilers: Wicke's vertical water-tube, equipped with Foster superheaters.
Total heating surface of each boiler, 2000 sq. ft.
Total refuse burned, 277,550 lb.

	Test results	Builders' guaranties
Total refuse burned per hour, in pounds	12,909	10,833
Total refuse burned per square foot of grate surface per hour, in pounds	80.6	60
Total clinker and ash, in pounds (approx.)	68,608	......
Percentage of clinker and ash to refuse burned	24.7	......
Maximum combustion chamber temperature	2,000° F.	......
Minimum combustion chamber temperature	1,700° F.	1,250° F
Average combustion chamber temperature	1,845° F.	1,500° F.
Average steam pressure (gage), in pounds	120	......
Average temperature of steam	523° F.	......
Average superheat	173° F.	100° F.
Average temperature of feed-water	206° F.	......
Total water fed to boilers, in pounds	397,162	......
Total water evaporated, from and at 212° F., in lb.	450,382	......
Total water evaporated per pound of refuse, in lb.	1.62	1.3
Water evaporated per pound of combustible, in lb.	2.15	......
Total boiler horse-power developed per hour	607	......
Estimated horse-power used in plant for 75 kw. non-condensing, turbo-generator set and boiler feed pump	118	......
Excess boiler horse-power	489	330
Average air pressure under grate, in inches	3¼	......
Average air temperature	252° F.	......
Average stack draft, in inches	0.72	......
Average CO_2, percentage	11.43	......
Total number of charges, both furnaces	447	......
Average weight of charge, in pounds	621	......
Total number of clinkerings, both furnaces	64	......

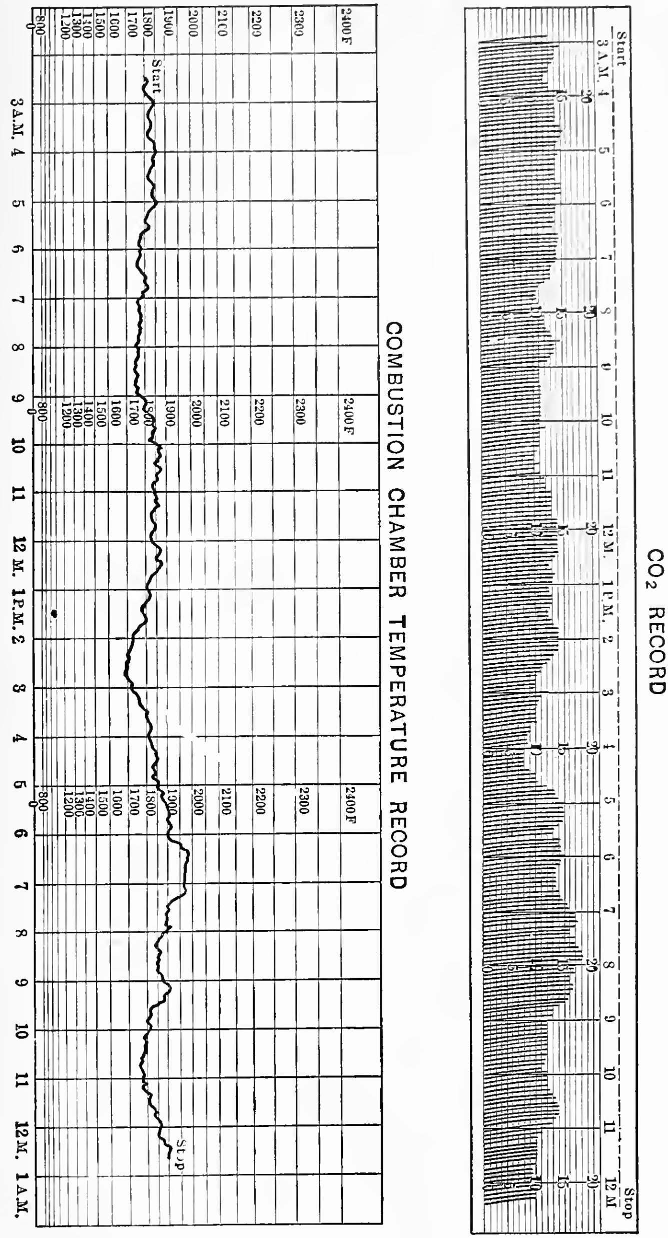


Fig. 93.—Test of Heenan Incinerator, Savannah, Ga., August 21, 1914.

of water, the average being 0.69; and the CO_2 in the gas ranged from 7 to 12%, with an average of 9.6%.

The plant at **Topeka**, also designed by Mr. Lewis, is practically a duplicate of the one at Racine.

Table 115 gives the work elements that were obtained during official tests made at the Clifton incinerator, built by the Power Specialty Company, in 1914, for summer and winter refuse.

Table 116 gives the results of a test made in 1914 in **Savannah** of a new Heenan incinerator, under the direction of Mr. E. R. Conant, City Engineer. The water evaporated from 1 lb. of refuse, from and at 212° Fahr., was 1.62 lb. The details of the test, which lasted 21½ hours, and of the cost of operation, according to contract and actual, are given. Fig. 93 gives diagrams of the CO_2 record and of the temperature in the combustion chamber.

The test was made with a running start. All the hoppers were empty, and were then charged with the test mixture. All combustion chamber temperatures were taken with a thermo-electric recording pyrometer. All other temperatures were taken with mercury thermometers. The water was measured with a Worthington hot-water meter. Steam pressures were taken with a recording pressure gauge connected with the main steam line.

The steam was delivered to the main steam header of the waterworks pumping station, and used to operate one 10,000,000-gal. pumping engine and one 1850-cu. ft. cross-compound condensing air compressor. From 12:15 to 5:10 P.M. the pumping engine was speeded up. The steam was also used to operate all prime-mover units used in generating power in the plant. The safety valves on the boilers were popping off from 5:30 until 6:30 P.M.

At 7 A.M. of August 22 all the refuse in the storage pit had been burned, and from that time until 8 A.M. insufficient refuse was delivered to keep the plant going at full capacity.

The weather during the test was hot and humid, and there were occasional showers. All the calculations were based on the standards of the American Society of Mechanical Engineers.

Cost of Operation—Based on Contract

Hoisting,	1 man per 8-hour shift at..	$2.40	$2.40
Stoking,	4 men per 8-hour shift at...	2.40	9.60
Clinker removing,	1 man per 8-hour shift at...	1.50	1.50
Engineer,	1 man per 8-hour shift at...	4.00	4.00
Total labor charges per shift................			$17.50
Total labor charges per 24 hours...............			52.50
Total labor charges per ton, at 130-ton rate.....			0.404

Cost of Operation—Based on Actual Tests

Hoisting,	1 man per 8- hour shift at. .	$2.25	$2.25
Stoking,	4 men per 8-hour shift at. . .	1.75	7.00
Clinker removing,	1 man per 8-hour shift at. . .	1.50	1.50
Engineer,	1 man per 8-hour shift at. . .	4.00	4.00

Total labor charges per shift.	$14.75
Total labor charges per 24 hours.	44.25
Total labor charges per ton, at 130-ton rate.	0.3403
Total labor charges per ton for 138.75 tons in 21½ hrs.	0.318

San Francisco, on the advice of Hering, prepared specifications for the construction of an incinerator at Islais Creek. The Power Specialty Company was the lowest bidder, and built the works. The guaranties were clear and reasonable in their intent to secure satisfactory results, but, in a strictly literal interpretation, contained several requirements which, under existing conditions, were not quite fulfilled. The incinerator was first operated in August, 1913. In February, 1914, it was shut down in order to put in a new and better clinker handling system; it was again operated in August, 1914, and tested for a period of thirty days from September 4 to October 3, 1914.

TABLE 117.—Analyses of Refuse Delivered for Test of Islais Creek Incinerator, San Francisco, 1914

Date	Sample No.	Tons	Grab-buckets hoisted	Samples taken	Moisture	Combustible
Sept. 23	1	121.61	181	22	55.9%	25.9%
" 24	2	92.13	132	22	53.1	24.9
" 25	3	104.21	150	25	56.5	23.4
" 26	4	109.92	143	24	52.9	26.5
" 28	5	113.94	162	27	55.4	26.5
" 29	6	134.39	188	30	47.7	23.9
" 30	7	138.40	180	30	52.5	25.7
Oct. 1	8	110.83	156	25	48.9	28.0
" 2	9	104.45	123	20	48.6	27.3
Totals. . . .	. . . .	. . . .	. . . .	. . . .	471.5	232.1
Averages for the nine days. . . .			. . . .	. . . .	52.4%	25.8%

An analysis of the refuse delivered by the city during the test is given in Table 117. Table 118 is a record of the thirty-day test, and Table 119 shows the evaporation trial.

TABLE 118.—RESULTS OF TEST OF ISLAIS CREEK INCINERATOR, SAN FRANCISCO, CAL.

30-day test

Date of test	Sept. 4 to Oct. 3, 1914
Duration of test in actual operation	26 days
Total burning for entire period	449.0 hours
Average burning hours per day for 26 days	17.6 "
Refuse: *	
Received for the period, Sept. 4 to Oct. 3	2,831.0 tons
Average for the 26 days, per day	108.88 "
Moisture per ton at 52.4%, mean of 9 samples	1,048.0 lb.
Combustible per ton at 25.8%, mean of 9 samples	516.0 "
Average quantity of ash	21.8%
Grates:	
Area of one grate	15.4 sq. ft.
Number of grates per furnace	4
Total grate area for two furnaces	123.2 sq. ft.
Refuse burned per hour during test	12,600 to 13,700 lb.
Refuse burned per hour per square foot of grate surface	102 to 111 "
Water:	
Average to boilers during burning time	190,085.0 "
Average to boilers shut-down time	10,060.0 "
Total average to boilers for 24 hours	200,145.0 "
Feed-water temperature	68.0 deg.
Evaporation equivalent: †	
Factor of evaporation for burning period	1.264 lb.
Factor of evaporation for shut-down period	1.19 "
Equivalent evaporation, from and at 212°, for burning period	240,267.0 lb.
Equivalent evaporation, from and at 212°, for shut-down period	11,971.0 "
Total of equivalent evaporation, from and at 212°	252,238.0 "
Steam:	
Pressure by gage, mean of 26 days	148.0 "
Temperature, saturated steam at pressure	365.0 deg.
Temperature, superheated steam	487.0 "

* No tests were made to determine the percentages of garbage, rubbish, fine ash, etc., in the refuse. So far as known, the quality of the refuse was practically the same as when the analyses incorporated in the specifications were made. There was practically no coal ash, and the refuse might be classified as a mixture of garbage and rubbish with a considerable quantity of metal, *i.e.*, wire, tin cans, etc.

† The average evaporation during the 30-day test, in pounds of water per hour, from and at 212° F., was 1.22. This was higher than during the two evaporation tests for the actual net cost of incineration, in which tests the corresponding figure was 1.15 lb. per hour, from and at 212° F., per pound of refuse.

TABLE 118—(*Continued*)

Degrees of superheat	122.0 deg.
For generator drive, 28.17 lb. per kw.-hr.	9,817.0 lb.
For feed pump, 29.55 lb. per 1000 lb	5,914.0 "
Available balance for revenue	236,507.0 "
Power:	
Total output by generator, average for 26 days	368.5 kw.-hr.
For incineration	348.5 "
Cost of incineration:	
Assumed revenue from steam at \$0.04, 100 lb. steam	\$94.60
Cost of labor = 17.6/22 of \$66.00	52.80
Assumed net profit	41.80
Cost of incineration per ton of garbage:	
Assumed revenue from steam per ton	0.8688
Cost of labor = 17.6/22 of \$66.00/108.88	0.4849
Assumed net profit per ton	0.3839
Guaranteed profit per ton, standard garbage	0.255
Corrections for excess of moisture—minus	0.0538
Corrections for excess of combustible—plus	0.0896
Corrected guaranteed profit per ton	0.291
Difference between assumed net profit and corrected guaranteed net profit per ton more than guaranty	0.0929

After this test the City Officers rejected the plant on the ground that it did not fulfill all the guaranties. The case was taken into Court, tried, and, after many witnesses had been heard, was decided in favor of the contracting company.

The City had claimed that the test showed a nuisance from the works, in that odors, obnoxious gases, smoke, and dust escaped from the buildings or chimneys. The evidence of many witnesses clearly showed that any nuisance during the test was either trivial, unreliable, or emanated from other plants than the incinerator, or when the latter was not operating under contract conditions; and steam escaping from the chimneys had popularly been mistaken for smoke.

The City had claimed that the combustion chamber temperature at times had fallen below the specific minimum of 1250°. According to the evidence, this had been the case only near the starting time, or momentarily when greatly disproportionate combustible refuse had been delivered by the City.

The City had claimed that all the residue should be burned thoroughly hard. Proof was presented indicating that, as in all cases of city refuse containing little or no ashes, the San Francisco refuse could not always produce a thoroughly hard clinker.

TABLE 119.—EVAPORATION TEST OF ISLAIS CREEK INCINERATOR, SAN FRANCISCO, CAL.

(A part of the 30-day test.)

Date of test	October 2, 1914
Duration of test	16.4 hours
Garbage:	
For the day	104.45 tons
Moisture per ton at 48.6%	972.0 lb.
Combustible per ton at 27.3%	546.0 "
Water:	
To boilers for burning period, 16.4 hr	190,460.0 "
To boilers for shut-down period, 7.5 hr	13,330.0 "
Total to boilers from starting Oct. 2 to starting Oct. 3.	203,790.0 "
Feed-water temperature	68.0 deg.
Evaporation equivalent:	
Factor of evaporation for burning period, 16.4 hr	1.26
Factor of evaporation for 7.5 hr., shut-down period	1.19
Equivalent evap., from and at 212°, for 16.4-hr. period.	239,979.0 lb.
Equivalent evap., from and at 212°, for 7.5-hr. period.	15,862.0 "
Total equivalent evaporation, from and at 212°	255,841.0 "
Steam:	
Pressure by gage	147.0 "
Temperature, saturated steam at pressure	364.5 deg.
Temperature, superheated steam	480.1 "
Degrees of superheat	115.5 "
For generator drive, 28.17 lb. per kw.-hr	9,975.0 lb.
For feed-pump, 29.55 lb. per 1000 lb	6,022.0 "
Available balance for revenue	239,844.0 "
Power:	
Total output by generator	374.7 kw.-hr.
For clinker	20.6 "
For incineration	354.1 "
Cost of incineration for the day:	
Assumed revenue from steam at $0.04 per 100 lb	$95.94
Cost of labor = 16.4/22 of $66.00	49.20
Assumed net profit	46.74
Cost of incineration per ton of garbage:	
Assumed revenue from steam at 4 cents 100 ib	0.9185
Cost of labor = 16.4/22 of $66.00/104.45	0.471
Assumed net profit per ton	0.4475
Guaranteed profit per ton of standard garbage	0.255
Correction for deficiency of moisture	0.0078
Correction for excess of combustible	0.1376
Corrected guaranteed profit	0.4004
Difference between assumed net profit and corrected guaranteed net profit per ton more than guaranty	0.0471

On the other hand, the City admitted that the average temperature was in excess of the guaranteed average of 1500°; that furnaces, flues, combustion chambers, etc., did not have to be shut down more than forty-eight hours in any one week in order to remove all dust and ashes; that the number of pounds of refuse burned per square foot of grate surface exceeded the contractor's bid; and that the cost per ton for incineration was less than the bid price.

We have here stated some of the details of this case for two reasons. First, to show the futility of specifying guaranties in too much detail, at the present stage of the still developing art of refuse incineration, instead of only the broad essential requirements; and secondly, to place before engineers and contractors questions in reference to guaranties which may arise in Court.

A careful study was made by Mr. J. J. Jessup for a refuse incinerator at **Berkeley,** in 1913, with the result that the Sterling design was adopted and built. In 1914 a test was made, with the results given in Table 120. The refuse consisted almost wholly of garbage and rubbish. The average moisture ranged from 48½ to 63%, and the average combustible only from 5½ to 17%. Consequently, the evaporation, from and at 212° Fahr., per pound of refuse, ranged only from 0.6 to 1.01 lb., but the incineration was without offensive odor.

At **Huntington** (population about 45,000), the garbage furnace designed by Mr. S. R. Lewis, was tested on October 26, 1914. The furnace is composed of two units, and has special quick-operating doors, but no storage bins. Natural gas is burned, though provision is made for the use of coal. The chimney is 125 ft. high and 26 in. in diameter.

The material burned was a mixture of kitchen garbage and general city rubbish, the latter weighing 22 lb. per cubic foot; the carcass of one horse, weighing 1200 lb. was burned.

The fires were started at 6:30 A.M., and 8000 cu. ft. of gas were burned to heat the furnace to 900° (combustion chamber) at 10 A.M. The material was introduced continuously from 10 A.M. until 5 P.M. It had all been burned at 6:30 P.M.

The maximum temperature in the combustion chamber was 1400°, the minimum, 1100°, and the average, 1230°. The temperature dropped to 900° almost momentarily when the door to the combustion chamber was opened.

In 8½ hours 25,860 lb. of refuse, or 3043 lb. per hour, were burned. This is at the rate of 84.5 lb. per square foot of grate area per hour, and it required 0.785 cu. ft. of gas per pound of refuse burned. This plant has recently been shut down.

In 1914 it was decided, on the recommendation of Hering, to build a mixed refuse incinerator in **Atlanta.** After competitive bids

TABLE 120.—RESULTS OF TESTS OF THE STERLING REFUSE INCINERATOR, BERKELEY, CAL., 1914

	Capacity test with wet garbage	Evaporation and temperature test with average garbage	Guaranteed figures
Dates	Jan. 10–31, 1914	Feb. 2–7, 1914	....
Number of days	19	6	....
Quantity of refuse burned, in pounds	1,261,350	373,040	....
Average number of tons per day	33.2	31.09	....
Average number of hours run per day	12.55	10.7	....
Average number of tons burned per hr.	2.65	2.89	2
Exceeding guaranteed capacity, percentage	33	44	....
Average weight of refuse per cubic yard, in pounds	818	744	....
Average percentage of moisture	63	48½	....
Average percentage of non-combustible	31½	34½	....
Average percentage of combustible in refuse	5½	17	....
Total quantity of water evaporated, in pounds	628,083	311,581	....
Evaporation, from and at 212° F., per pound of refuse, in pounds	0.6	1.01	1
Average boiler pressure (gage), in lb.	100½	97.3	....
Minimum temperature in combustion chamber	....	1,300°	1250°
Maximum temperature in combustion chamber	....	2,200°	....
Average temperature in combustion chamber	....	1,800°	....
Pounds burned per square foot of grate	71	77	53
Exceeding guaranteed capacity, percentage	34	45	....
Wages paid during test, per hour	$1.342	$1.342	....
Actual cost per ton	0.506	0.464	$0.52
Saving under guaranteed cost, percentage	2.7	10.8	....

the Power Specialty Company erected a Heenan furnace. It was completed early in 1915, and was tested from 1 P.M., May 26 to 6:10 A.M., May 27. Table 121 gives a summary of the test. It will be seen that the evaporation, from and at 212° Fahr., was more than 2 lb. of water per pound of refuse.

TABLE 121.—RESULTS OF TEST OF HEENAN REFUSE INCINERATOR, ATLANTA, 1915

Refuse fed into furnaces (of proportions specified in contract)	391,085 lb.
Dry clinker withdrawn	112,300 "
Percentage of water in clinker	13.45
Clinker, percentage of refuse	28.8
Refuse, less clinker	278,785 lb.
Water evaporated	530,258 "
Furnace hours	51.5
Duration of run	17 hr. 10 min.
AVERAGE QUANTITIES	
Steam pressure, absolute	190.05 lb. per sq. in.
Steam temperature	515.22° Fahr
Superheat	137.62° "
Feed-water, before passing through feed-water heater	78° "
Feed-water, after passing through feed-water heater	190.31° "
FACTORS OF EVAPORATION	
Boiler only	1.0706
Boiler and superheater	1.1508
Boiler and feed-water heater	1.186
Boiler, superheater, and feed-water heater	1.266
RATES	
Water evaporated per pound of material fired	1.3558 lb.
Equivalent evaporation, from and at 212° Fahr., per pound of material (refuse) fed into furnace:	
Boiler only	1.4509 lb.
Boiler and superheater	1.5594 "
Boiler and feed-water heater	1.6082 "
Boiler, superheater, and feed-water heater	1.7167 "
Water evaporated per pound of refuse fed to furnace, less clinker, observed	1.905 "
Equivalent evaporation, from and at 212° Fahr., per pound of material (refuse) fired, less clinker:	
Boiler only	2.038 "
Boiler and superheater	2.190 "
Boiler and feed-water heater	2.26 "
Boiler, superheater, and feed-water heater	2.41 "
CAPACITY PER 24 HOURS	
Based on 72 furnace-hours	273.5 tons
Average temperature, charging floor	121.5° Fahr.
Average temperature, out doors	75.7° "
Average difference	45.8° "

With reference to the test, it should be mentioned that Mr. E. H. Foster, of the Power Specialty Company, states that:

"Due to the excessive amount of garbage delivered with the refuse, the moisture ran much higher than the contract conditions called for, which made the chimney undersized when three furnaces were in operation, and it was found that the chimney draft had to be augmented by the installation of an induced-draft fan, which easily brought the plant up to capacity. If it had been known beforehand that the city collection was so deficient in household ashes, ample precautions could and would have been taken in the original design."

This case shows the importance of making sufficient analyses of the refuse (Chapter I), in order to design the plant properly and economically, and determine its best operation.

We have added the results of a test of an incinerator at **Ridgewood,** in 1916, which consumes only garbage and rubbish. No ashes were contained in the material delivered and no fuel was added. Table 122 gives the detailed results as recorded.

A comparison of the working elements of the plants at West New Brighton in 1908, and Clifton in 1913 is given in Table 123, to show the substantial progress made in the efficiency of incineration.

For other tests, see also under description of plants, Chapter X, F.

The successful operation of an incinerator requires careful attention and skilled labor. The handling of the fires is particularly important. It is not unusual to operate the furnace six days in a week. On Sundays and holidays, as well as overnight in small cities, the fires can be banked, with a small loss.

After a year of operation, the following rules were formulated for the guidance of the firemen at the Milwaukee incinerator:

"The following directions must be carefully observed in firing:

"(*a*) Always cover the fire as heavily and as rapidly as possible. With wet garbage, which is over 60% of the mixture, such cover can only be about 3 in. thick. With dry material, containing not over 50% garbage and considerable rubbish (say 10%), the fire can be covered 2 ft. thick or more. If the refuse is dry but compact, and therefore heavy, the cover shall not be over 1 ft.

"(*b*) Above all, keep the fire covered with fresh wet material all the time, until time for it to burn off before clinkering.

"(*c*) In banking up a fire to last, get in as little ash as possible—a bank of 75% garbage is best. This will prevent the clinker from being hard. A fire banked with ashes is difficult to draw out after sixteen hours.

"(*d*) In clinkering a fire, draw out as little fine ash as possible. The bed of coals left on the fire may be as deep as 4 in., but should not be much over this. If the coals are hot and well burned, cover them with a fresh charge at once.

TABLE 122.—RESULTS OF TESTS OF DECARIE INCINERATOR, RIDGEWOOD, BOROUGH OF QUEENS, NEW YORK CITY, MAY, 1916

(From *Engineering News*, September 28, 1916.)

Date of test	May 8	May 10	May 15
Unit tested	No. 1	No. 2	Nos. 1 and 2
Weather	Clear	Clear	Clear
Duration of test, in hours	17	15.5	17.5
Mixed refuse consumed—garbage, in pounds	74,770	71,325	141,681
Mixed refuse consumed—rubbish, in pounds	30,585	29,990	60,330
Total material consumed, in pounds	105,355	101,315	202,011
Guaranteed rated capacity of units operated, in tons per 24 hours	50	50	100
Percentage of material, garbage	70.9	70.3	70.1
Percentage of material, rubbish	29.1	29.7	29.9
Refuse consumed per hour, in tons	3.09	3.26	5.77
Equivalent incineration in 24 hours, in tons	74.16	78.24	138.48
Equivalent incineration per square foot of grate area per hour, in pounds	69.67	72.4	64.1
Labor cost, as per terms of contract	$22.31	$20.35	$36.09
Labor cost per ton, as per contract	42.3 c.	40.1 c.	35.7 c.
Actual labor cost, as operated by the city	$28.69	$26.16	$42.65
Actual labor cost per ton, as operated by the city	54.5 c.	51.6 c.	42.2 c.
Cost of fuel required per ton	0	0	0
Total cost of operation per ton, as per terms of contract	42.3 c.	40.1 c.	35.7 c.
Total cost of operation per ton, as actually operated	54.5 c.	51.6 c.	42.2 c.
Guaranteed maximum cost of operation, per ton	75 c.	75 c.	60 c.
Condition and quantity of smoke	Light white	Light white	Light white
Percentage of carbon in free state in the clinker	5.39*	6.58*	1.13
Percentage of ash and clinker produced	9.3	10.7	12.3
Temperatures, in degrees Fahrenheit:			
Average in combustion chamber, No. 1 unit	1040	......	1290
Average in combustion chamber, No. 2 unit	......	1161	1340
Maximum temperature in combustion chamber, No. 1 unit	1580	......	1650
Maximum temperature in combustion chamber, No. 2 unit	......	1600	1810
Average temperature of forced draft beneath grates	391	496	510
Average stack draft, in inches of water	0.94	0.99	0.98
Average steam pressure, in pounds per square inch:			
In No. 1 unit	86.2	......	96.0
In No. 2 unit	......	93.7	90.0

* The higher percentages of carbon in these two tests was due to the fact that the units were being overloaded to far above capacity, as rate of combustion per square foot of grate area will show, when compared with rate of combustion in third test, May 15th.

"(*e*) Start with a very low air supply—about ½ to 1 turn on the Milwaukee valves. Increase this to not over 3 turns as the fire grows. The tendency is to have an excess of air.

"(*f*) In clinkering, get the lumps out with the rake as much as possible, leaving the fine stuff behind.

"(*g*) The careful handling of firing tools is a matter of much importance, and should be impressed on the firemen from the start.

"(h) The life of the grates will be lengthened by shutting off the air valve tight during clinkering, and then opening it slowly.

"(i) If a fire is being banked for a short time, say eight hours, leave the back hearth clean. If it is going to be banked for a long time, so that new fires will have to be started, one charge can be left on the back hearth, because it will burn up before the furnace is cleaned and started again.

"(j) In filling the charging holes, put rubbish near the bottom and ashes on top. This will tend to throw the ashes forward and prevent heavy clinkers at the back. Rubbish can be burned rapidly under natural draft with the charging hoppers open, so that large quantities can be put in at a time.

"(k) The fire, if hot and in good condition, should be built up rapidly at the start, so as to cover the castings before they become heated.

"(l) Tools should be handled as near their center of gravity as possible."

TABLE 123.—COMPARISON OF WORKING ELEMENTS OF WEST NEW BRIGHTON AND CLIFTON INCINERATORS

	Cost per ton for supervision and labor	Pounds burned per furnace per man per hour	Pounds burned per square foot of grate per hour	Percentage of time furnace doors were open
West New Brighton, 1908..	$0.76	1357	54.3	73.7*
Clifton, 1913.............	0.41	3330	144.2	5.1

* Obtained after official tests.

E. BY-PRODUCTS

In several reports that have been made on improved refuse disposal works a revenue has been included, which could be derived from the utilization of steam produced in operation and the sale of clinker and flue dust. In some works, following the recommendations of these reports, the apparatus for utilizing the products of high-temperature incineration have not been put in. The expected revenue was not forthcoming, and consequently, financial disappointment resulted. It is desirable, therefore, in most cases, to determine the cost of making the by-products useful, and also to estimate the market value for them, so that their true value for each particular locality can be stated.

The principal methods of utilizing clinker are mentioned on page 393. Most of these methods involve the crushing and screening of the clinker; in some it is ground fine in mortar mills. A few methods for utilization are described more fully below, the data being taken largely from "Modern Destructor Practice," by W. F. Goodrich.

1. Steam.—The extent and kind of utilization of steam depends somewhat on the quantity produced. Statistics of the quantity produced under various conditions of operation have already been given in this chapter. The use to be made of the steam now remains to be considered.

Practically all incinerators that burn mixed refuse can produce steam. Some plants, and chiefly the smaller ones, may not furnish more than enough to operate the works. The larger the plant the more economically can the greater quantity of steam produced be utilized.

In Europe we find a variety of uses, including the partial or complete operation of electric lighting plants, electric railway systems, sewage pumping, and water pumping stations. The irregularity in the production of steam demands a utilization which requires no regular and constant power, such as grinding clinker for mortar, crushing for use on roads, making artificial stones and slabs, fertilizers, ice, loading storage batteries, etc. The first incinerators where the heat was utilized to produce electricity were those at Shoreham (England) and Westmount (Canada).

The success of these products in Europe has influenced American practice, and steam boilers have been built as integral parts of most of the high-temperature refuse incinerators in America. At only a few of them, however, has steam as yet been used to produce a revenue.

If steam is used for generating electricity, and particularly in smaller plants, it is advisable to put in electric accumulators, to average the production and increase the dependable power; or it may be preferred to add an auxiliary furnace for coal, oil, or gas firing.

The power required to operate an incinerator has varied from one-sixth to one-third of the entire power which it has produced, depending on the design and the way in which the works have been conducted.

In selecting a method for utilizing steam from an incinerator, it is necessary first to consider its rate of production. As refuse has so variable a calorific value, the rate of steam production will not be uniform, as shown by the Milwaukee test. Furthermore, a refuse incinerator may not have material delivered to it continuously for operation, as the collection is suspended on holidays and Sundays. The total quantity of refuse incinerated in Milwaukee during 1916 is shown in Table 124.

The surplus steam at the Milwaukee incinerator is converted into electric power and used to pump flushing water into the Milwaukee River (see Table 125). This is a favorable sort of load for an incinerator, because the pumps can be shut down without objection at times

when the incinerator is not working. When the steam is used for pumping water or sewage, or for lighting, and it requires regular service at certain hours, or continuous twenty-four-hour service, it is advisable to have supplementary sources of power at the incinerator, as at Westmount. If the pumps are operated by electric motors, the additional power can come from other power plants. With steam-driven pumps, stand-by boilers are required. In most cases, the incineration furnishes only a part of the steam required for outside purposes. Under these conditions, however, more of the incinerator

TABLE 124.—TOTAL REFUSE INCINERATED IN MILWAUKEE (CITY AND PRIVATE COLLECTIONS), 1916

Month	Total hours operated	Total pounds, mixed refuse incinerated	Average evaporation per pound of mixed refuse
January	608	8,689,780	1.784
February	592	8,136,140	1.802
March	648	8,688,100	2.060
April	656	7,537,720	1.494
May	680	9,335,800	1.547
June	656	9,553,680	1.887
July	640	9,640,020	1.771
August	680	10,766,800	1.873
September	656	10,160,360	1.924
October	664	9,748,820	1.954
November	656	7,770,000	1.771
December	648	8,523,500	1.741
Totals	7784	108,550,720	1.794

Average percentage of refuse incinerated during 1916: Garbage, 69.92%; ashes, 23.92%; rubbish, 5.85%; manure, 0.13%.

steam can be used than otherwise, as it will not be necessary to keep the load wholly below a safe minimum steam output. The irregularities in the rate of production of the incinerator steam are balanced by the larger quantity obtained from the additional coal-fired boilers.

An interesting use for steam has been suggested at Milwaukee and at New York, namely, to operate ice plants, but not actually tried. Yet it would seem to be especially appropriate, because the application can be adapted so readily to a varying production of steam. The same may be said of loading storage batteries.

The utilization of waste heat from garbage furnaces is seldom attempted. At Minneapolis, where the furnace is water-jacketed

and the grates are made of water tubes, the heat is used merely to warm the feed-water for a boiler. This pre-heating is done in the walls and grates of the furnace. At other plants, water is heated to be used in washing wagons and for other cleaning at the plant.

2. Clinker.—At many incinerators, particularly in England and Germany, crushed clinker is made, to be used in place of broken stone or gravel, for ballast or aggregate in concrete, for paving and building blocks, flagstones, and bricks, as mentioned below. It has been found

TABLE 125.—ELECTRIC POWER DELIVERED FROM THE MILWAUKEE INCINERATOR POWER PLANT TO OPERATE THE MILWAUKEE RIVER FLUSHING PLANT DURING 1918 AND 1919.

Water lifted 2.7 ft.

Month	Hours operating flushing station		Kilowatts operating flushing station		Kilowatt-hours delivered to flushing station	
	1918	1919	1918	1919	1918	1919
January......	0.4	......	......	......	242	......
February..... March.......	No flushing necessary					
April..........	1.0	15.2	340.0	340.0	340	5,212
May..........	148.1	283.1	330.0	320.0	48,922	90,640
June..........	409.2	500.1	330.0	297.3	135,180	148,824
July..........	207.1	594.0	330.0	282.3	68,393	167,680
August.........	......	569.5	......	274.0	......	156,160
September......	......	499.1	......	282.2	......	140,800
October	......	420.6	......	291.4	......	122,880
November......	208.4	137.5	320.0	271.0	66,773	38,400
December......	No flushing necessary					

especially useful for concrete in pavement foundations under a wearing surface, and for sewage filter beds. Fine screenings have been used also for surfacing smooth pavements and between car tracks to reduce slipperiness. Fine ashes screened from the clinker at Portland, Ore. (1916) were sold as a fertilizer. In Zurich, Switzerland, they are used as a disinfectant in outside toilets or earth closets.

Flue dust has not as many possibilities for utilization as clinker. A sample from the Milwaukee incinerator was submitted to an asphalt chemist, who reported that it was a satisfactory material to use as a filler in asphalt paving mixtures.

An excellent record of clinker utilization has been made by the Glasgow Corporation, as shown in Table 126. The revenue shown in this table is equivalent to approximately 60 cents per ton of clinker sold. Some revenue from clinker has also been received at a few American incinerators, as at Seattle and West New Brighton.

TABLE 126.—REVENUE FROM CRUSHED AND SCREENED CLINKER, GLASGOW, SCOTLAND

Year	Tons sold	Revenue
1901	9,753.2	$5,495.00
1902	9,332.9	4,885.00
1903	11,938.3	7,060.00
1904	15,292.0	7,950.00
1905	14,693.0	8,465.00
1906	17,635.0	10,880.00
1907	13,975.0	8,140.00
1908	13,307.0	8,555.00
1909	13,807.0	8,895.00
1910	11,768.7	7,910.00

All the above uses have been tried on a working scale and found to be more or less successful. In many cases a net revenue has resulted. The question of clinker utilization should always be considered in the design of new works. Local conditions of available dumping areas, and opportunities for the sale of products, will largely control the decision as to whether or not to put in clinker-handling machinery.

The handling of the clinker from the furnace to the dump, to the freight car, or wagon, is also of importance, when considering the whole cost of operation. At many plants, the clinker car is pushed by hand to the dumping place. At some of the more recent plants the cars are suspended from overhead rails and operated by a motor. At the Westmount incinerator, the clinker car bodies are taken to the dump near the building by an overhead cable. The loaded cars are pushed under the cableway and the bodies are picked up by an electrically-operated carriage controlled from switches in the building. The carriage takes the car body to the dump, unloads it, and returns it to the building.

Cars for handling hot clinker need careful design and construction. Standard contractors' dump cars, with a capacity of 1 cu. yd., did not last more than four months at Milwaukee, when they had become so distorted that they could not be dumped. Cars with cast-iron bodies

were tried, but were found to be too heavy. The car body finally adopted consisted of a frame made of 4 by 4-in. angles to which plates of $\frac{1}{4}$-in. wrought iron were bolted. When the plates became bent, they were taken off and straightened.

3. Paving Blocks.—Experimental work, on a considerable scale, for making paving blocks of clinker and asphalt, has been conducted at the Kensington incinerator in London. The process and results are described by Goodrich, as follows:

"The clinker is taken direct from the cells and fed into a powerful grinding mill, where it is ground sufficiently to pass a fine screen. The screened material is then fed, by means of horizontal pushers, into the lower part of a steel elevator, which is encased in steel sheeting, and is elevated to the first floor of the building, and passed through a shoot into a revolving steel dryer, where the screened clinker is subjected to an intense heat. Passing from the dryer, it is again elevated to the floor above, and is then fed into a measuring hopper having a bottom-lever discharge. While this part of the process is taking place, the ground asphalt is being prepared. The asphalt is hoisted to the top floor of the building and fed into large melting vats, which are of special construction, arranged with heating coils and a superheated steam supply for the melting of the asphalt and for maintaining the same at a high temperature. When in a suitable condition a supply of residuum oil is introduced.

"From the melting tanks the mixture passes into a conical measuring vessel; when the desired volume is reached, this vessel is carried by means of a mono rail to the mixer, into which the ground clinker and asphalt mixture are simultaneously introduced and thoroughly mixed. The mixer is of strong construction, being made in steel boiler plate, and is provided with pug arms and substantial gearing.

"When thoroughly mixed at an even temperature the material is discharged into a steel shoot which communicates with the block press.

"The block press is of massive construction, and exerts a pressure of 100 tons upon each block; the press is automatic in action; as one hopper is filled by the men in charge, another comes under the dies of the press, and as each block is formed it is pushed forward over a smooth iron table and conveyed to the cooling tank.

"For the manufacture of 1000 paving blocks about $3\frac{1}{2}$ tons of clinker are used with 1 ton of asphalt, the weight of the finished blocks being about 4 tons; the loss in weight is accounted for by the moisture. The cost per 1000 paving blocks is about £4 for material and 14 shillings for labour.

"It is claimed that the blocks are resilient, as noiseless as wood paving, non-porous, sanitary, and unaffected by temperature. Upwards of one million of these blocks have been laid in Queen's Gate, Hyde Park, W., Ledbury Road, Bayswater, and in Stamford Street, near to the Royal Albert Hall, Kensington, W."

4. Flagstones for Sidewalks.—The clinker is used in making flagstones. It is first crushed to about $\frac{3}{8}$ in. in size and is then mixed

wet with Portland cement in the proportion of one part of cement to three parts of broken clinker. The mixture is then placed in an iron mould to make a slab from $2\frac{1}{2}$ to 3 in. thick. The surface dimensions vary from 2 ft. square to 2 ft. by 3 ft. The mixture is compacted in the mould with a heavy maul or under a hydraulic press. The surface is troweled smooth or given a finish of granite chippings. The flags should stand for four to six months in summer weather before being used. At the Bristol Corporation Works, in England, it is stated that one ton of clinker and $\frac{1}{3}$ ton of cement will make 16 sq. yd. of flags. The daily output is 97 sq. yd. per working day of 9.5 hours. At Liverpool it is stated that three men and an apprentice, working with a hydraulic press, could make about 45 sq. yd. of flags per day. At this plant, 53,684 sq. yd. of flags were made in 1909. Maxwell reports the following strengths for machine-made clinker concrete flags, 2.5 in. thick. (He does not mention the other dimensions):

Age of flag	Breaking load applied at center of flag
4 months..........	1804 lb.
4 "	1474 "
4 "	1742 "
4 "	1917 "
4 "	1608 "
4 "	1752 "
6 "	2061 "
6 "	1966 "
4 "	1859 "
4 "	1659 "
4 "	1589 "
Average.......	1766 lb.

A three-mould hydraulic flag press is made by Fielding and Platt, Ltd., in England. This method of clinker utilization is applied in more than a dozen cities of England, where the cost of making these flagstones has been about 40 cents per square yard.

5. Bricks.—Making building brick of crushed clinker and lime or cement is practiced less extensively than making flags. Nevertheless, it is a promising method of utilization. There is a plant in operation at Nelson, England, with a capacity of about 20,000 bricks per week. This plant comprises a ball mill for grinding lime, a 9-ft. perforated grinding mill for clinker, a clinker screen, a patent hydrating

mixer, a final mixer, brickwork silos, an "Emperor" press, and a hardening chamber with a capacity for 7000 bricks. The plant is electrically driven, requiring about 28 h.p. for grinding and 12 h.p. for mixing and brick making. The clinker is ground, mixed, and deposited in the silos on three days of the week, and the bricks are made on the others. The steaming of the bricks is done at night with steam made by the incinerator. Three men are required to operate the plant, and 4.5 tons of lime are used for 18.000 bricks. The time required for the whole process is from thirty to forty-eight hours. Tests of these bricks are recorded in Table 127; the cost of making them was about $4 per thousand.

F. PLANTS BUILT AND RESULTS OBTAINED

Many successful applications of the principles, designs, and practice described herein have been made, and in both America and Europe many examples exist. The foreign plants have been designed for incinerating a mixture of garbage, rubbish, and ashes. In the United States there are a number that incinerate a mixture of only garbage and rubbish—ashes being separately disposed of by dumping. The heat generated by the latter mixture is much less, so that a utilization of steam is frequently impracticable without the addition of extra fuel. Formerly, there were many furnaces in the United States where garbage alone was burned. As this always required the addition of coal, oil, or gas to destroy the garbage, thereby adding considerable expense, such garbage furnaces are frequently operated at relatively low temperatures.

We shall describe a few incinerators and garbage furnaces which are typical and indicate the progress that has been made.

1. West New Brighton.—The refuse incinerator built in 1908 at West New Brighton, under the direction of Mr. J. T. Fetherston, is one of the first plants in America, and is an excellent example of the hand-charged, back-fired type. It has a rated capacity of 60 tons of mixed refuse per twenty-four hours. The plant is on the water-front, about 250 ft. north of the main street, and serves a district extending along the northern shore of Staten Island for about 4 miles. The area of the district is about 5000 acres, and the population served about 35,000. The population is mixed residential, business, and manufacturing, and produces about 1.6 tons of mixed refuse per 1000 population per day. During 1911 this refuse was composed of 68% of ashes, 24.9% of garbage, and 7.1% of rubbish.

The incinerator is housed in a three-story, reinforced concrete

TABLE 127.—TESTS OF CLINKER BRICKS MADE AT NELSON, ENGLAND, 1914

(Goodrich, "Modern Destructor Practice," p. 133.)

Description	Dimensions, in inches	Area of base, in square inches	Compressive strength, in pounds		
			Cracked slightly	Cracked generally	Crushed
Composition brick, gray, no recess, made from destructor clinker and 6% lime......	2.77, 9.00 by 4.36	39.24	222.000	259.800	262.000
do.	2.95, 9.02 by 4.40	39.69	199.900	230.800	248.000
do.	2.80, 9.00 by 4.34	39.06	154.600	222.700	222.700
do.	2.63, 9.02 by 4.36	39.33	150.900	206.000	206.000
do.	2.62, 9.02 by 4.36	39.33	134.500	204.700	204.700
do.	2.80, 9.00 by 4.36	39.24	130.700	159.000	159.000
Mean..................	....	39.31	165.417	213.833	217.067
Pounds per square inch.....	....	......	4208	5440	5522
Tons per square foot.......	....	......	270.6	349.8	355.1

TESTS FOR ABSORPTION

Description	Before immersion	After 24 hours immersion	Difference	Percentage of absorption	
	Pounds	Pounds	Pounds		
Composition brick, gray, no recess.....	9.330	9.679	0.367	3.93	6.72
do.	8.510	9.273	0.763	8.97	
Do., recessed one side................	8.573	9.195	0.622	7.26	

COMPARISON OF ANALYSES OF LIME BRICKS AND CEMENT CONCRETE

Clinker and lime bricks made with about $8\frac{1}{2}$% of lime		Clinker and cement concrete made from 1 cement and 5 clinker	
Lime........................	17.0%	Lime........................	16.8%
Silica........................	32.5	Silica........................	32.2
Alumina.....................	14.8	Alumina.....................	14.1
Ferric oxide....................	18.2	Ferric oxide....................	16.8
Magnesia and alkalies..........	5.5	Magnesia and alkalies..........	5.8
Water in combination..........	12.0	Water in combination..........	14.3
	100.0%		100.0%

building, about 50 ft. square and 45 ft. high. The concrete chimney connected with the furnace is 125 ft. high, and is lined with fire-brick to a height of 20 ft. On the top floor of the building is the dumping room, which is approached by an inclined roadway from the main street. The storage pit is reached through a large doorway fitted with a vertical steel roller door. The dumping platform is about 40 ft. square. Extending across the top of the pit there are two runways on which the wagons are backed before they are dumped. The pit has a capacity of 120 cu. yd., and is divided into four sections, so that different grades of mixed refuse can be stored separately, if desired.

The storage pit opens on the level of the charging floor at the back of the furnace. There is just sufficient space between the pit openings and the furnace doors to permit of easy shoveling.

The furnace comprises four grates, a combustion chamber, a water-tube boiler, an air heater, and the necessary connecting flues, ashpits, and accessories. Fig. 94 shows a plan and sections through the furnace, and Fig. 95 is a general view of the plant.

Each grate slopes about 3 in. toward the clinkering door, and is made up of six cast-iron slabs, about 5 ft. long and 10 in. wide, set side by side, and drilled with two lines of $\frac{1}{8}$-in. holes. This gives an individual grate area of 25 sq. ft. Each grate is surrounded with an inclined cast-iron curb. The top of the furnace is arched over each grate, so that an undulating fire-brick surface is exposed to the hot gases, producing a reverberatory effect, and thus mixing the products of combustion. The crown of the arch is from 3 to 4 ft. above the grates.

The products of combustion pass over the several grates into the combustion chamber. This is 10 ft. square, and nearly 20 ft. deep, forming a pocket for collecting dust.

From the combustion chamber, the products of combustion pass to a 183-h.p. Babcock and Wilcox, water-tube boiler, thence to the air heater, and finally to the chimney. The air heater consists of a rectangular box, about 10 ft. long and 5 ft. square, filled with vertical tubes. The products of combustion pass through these tubes, up on one side of a central partition and down on the other. The air for the draft, which has been drawn by the fan from the various rooms in the building, is forced through the heater in the spaces between the tubes and then drawn under the clinker pits, from which it passes either up through grates in the clinker pits or directly into the ashpits and thence to the refuse through the holes in the grates.

The ventilating system is arranged so that all the air can be drawn from the dumping room, from the clinkering room, or from the furnace room, as desired. The plant is equipped with a full

set of recording instruments, and valuable records of operation are available.

The clinker is withdrawn by hand through openings in the front of the furnace, and dropped through trap doors into a clinker cooling

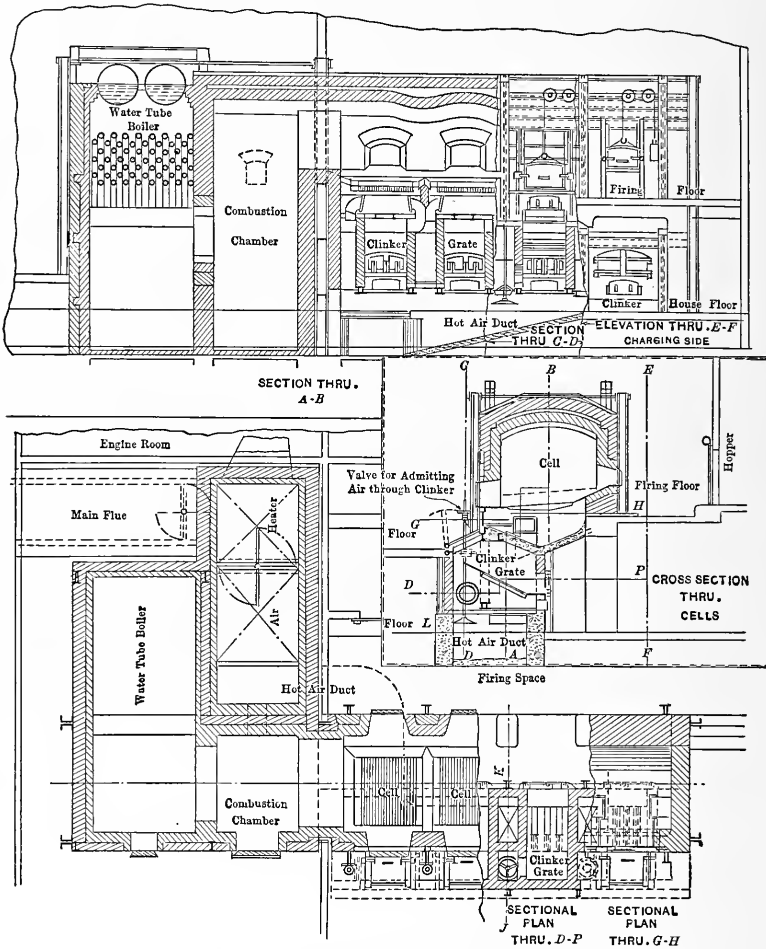


Fig. 94.—Plan and Sections, West New Brighton Incinerator.

chamber under the ashpits. From the cooling chamber it is taken in wheelbarrows to the dump, and has been used for making concrete and for filling.

The daily report sheets of the operations conducted at the West New Brighton and Clifton incinerators include the following:

Title and name of employee and his badge number; the time of his arrival and departure and the hours he worked, together with the rate of wages and their amount. His absences and vacations are also recorded. His work is stated under the headings: Supervision, operating machinery, feeding furnace, removing clinker, wheeling clinker, non-productive, weighing refuse, watching, etc.

Separate accounts are kept of each repair job, and also of all supplies consumed and materials used.

2. Clifton.—The refuse incinerator at Clifton, on Staten Island, N. Y., completed in 1913, is a development from experiments at the

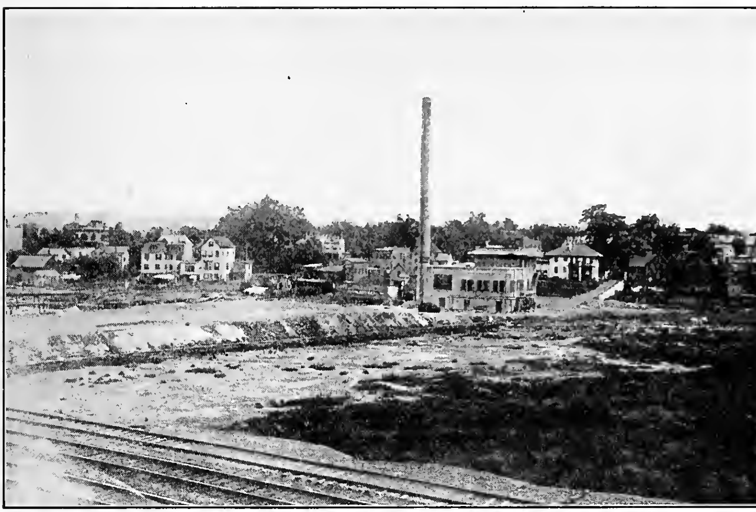


Fig. 95.—View of West New Brighton Incinerator.

West New Brighton plant with mechanical appliances for charging and clinkering. The plant is an excellent example of the mechanically-operated type. It consists of two 45-ton furnace units with two 150-h.p. boilers, one 50-kw. electric generator, a hydraulic pump, an accumulator, a clinker crusher and screen, and other accessories. Each furnace comprises three grates, each fitted with hydraulically-operated charging, clinkering, and clinker-discharging devices, and three clinker-cooling chambers. The plant is about two blocks north of a main street and within a block of dwelling houses.

The furnaces are housed in a three-story concrete and brick building, with a brick chimney and an inclined roadway approach. The collection wagons drive to the upper floor, and dump from either of

two sides into a storage pit near the center of the building. The pit opens on the charging floor below. The furnaces are set on each side of the storage pit. Just below the charging floor, between the pit and the furnaces, there are six charging pans, one for each grate. The refuse is thrown into them by the firemen. A hydraulically-operated ram pushes the loaded pan into the furnace above the grate, which it covers completely. When the pan is withdrawn, the back is held in place, so that the refuse falls off the end and is distributed evenly over the fire.

Clinkering is accomplished by pulling out the grate and allowing the clinker to fall into the cooling chamber below. The grate is made of channel-shaped, flat grate-bars, with two ridge-bars projecting about 6 in. above it. These grate-bars are carried on a strong cast-iron frame attached to the piston rod, the frame running on rollers. The ridge-bars form weak sections in the clinker, for easier breaking. Each ridge-bar turns up to form a nose or hump at its extreme end. As these humps pass through the clinker they break it up into small lumps. The ram pulls the grate into a closed chamber, to prevent the entrance of cold air. After the clinker has fallen into the cooling chamber, the grate is put back into its regular position.

The clinker-discharging device consists of a piston or pusher, which fits the cooling chamber. A forward stroke of this pusher forces the clinker out through the clinker door into a car or skip for removal. The clinker cars are suspended from an overhead rail which extends to the crusher, set in a pit below the ground level. The crushed clinker is elevated to screens, and the screened clinker is stored in an elevated bin for delivery to wagons. A baling press for tin cans is also provided.

The products of combustion pass through combustion chambers, boilers, and air heaters on their way to the chimney. These parts are arranged substantially as in the New Brighton plant. Ventilation is provided for the different portions of the building in connection with the forced draft. A section through a furnace is shown in Fig. 96. Fig. 97 is a general view of the plant.

3. Milwaukee.—In 1908, after a thorough study of the problem, the construction of an incinerator of 300 tons daily capacity was recommended to the city. It was built in 1909, and its operation began in 1910. It is the largest incinerator in the United States. The refuse of the city is divided into two classes: First, garbage, which is delivered to the incinerator from the entire city; and second, the ashes and rubbish, delivered only from about one-third of the city. Some manure is also delivered.

In 1917 the average percentages of refuse incinerated were as

follows: Garbage, 68.8%; ashes, 26.5%; rubbish, 4.5%; manure, 0.17%. Therefore, the proportion of the ingredients differs from that

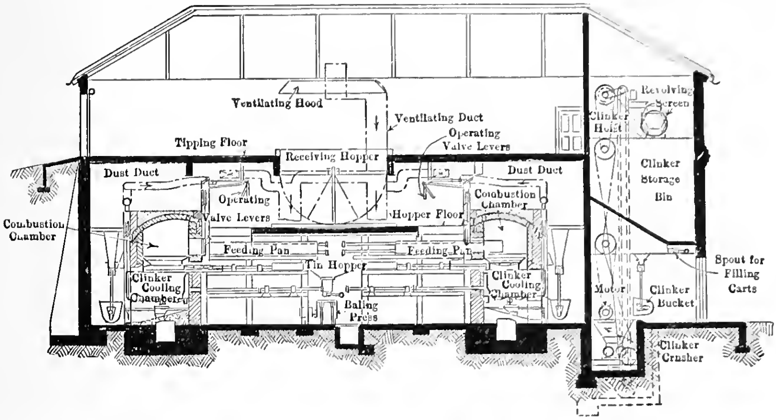


Fig. 96.—Section through Clifton Incinerator.

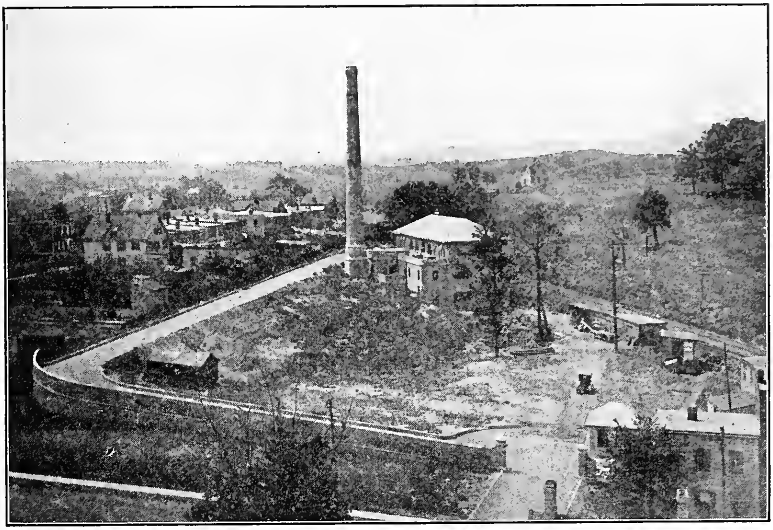


Fig. 97.—View of Clifton Incinerator.

generally found in Europe and in most American cities, in that a much larger percentage of garbage per ton must be incinerated. Table 128 shows the refuse incinerated monthly and also the average steam production.

TABLE 128.—REFUSE INCINERATED MONTHLY IN MILWAUKEE DURING 1919 (CITY AND PRIVATE COLLECTIONS); AND STEAM PRODUCTION

Feed-water pumped to boilers at average temperature of 180° F.

Month, 1919	Total hours operated	Total pounds of mixed refuse incinerated	Total pounds of feed-water delivered	Average evaporation, or pounds of steam produced per pound of mixed refuse
January	664	6,622,900	4,124,892	1.605
February	608	5,139,760	3,876,635	1.325
March	664	6,080,540	4,343,828	1.399
April	656	5,704,240	4,805,690	1.186
May	660	6,204,660	5,534,286	1.121
June	640	7,255,140	6,242,760	1.162
July	688	8,242,960	7,066,051	1.166
August	664	8,700,160	6,782,052	1.282
September	656	8,765,400	6,221,687	1.408
October	680	8,263,340	6,177,100	1.345
November	624	6,707,780	4,776,733	1.404
December	656	6,717,640	4,304,452	1.560
Totals	7860	84,404,520	64,256,166	1.315

Analysis of refuse incinerated during 1919: Garbage... 77.00%
Ashes..... 18.70
Rubbish... 4.23
Manure... 0.07

The plant is in the city, at the mouth of the Milwaukee River, and serves a population of about 450,000. Figs. 98 and 99 show a general plan and both longitudinal and cross-sections.

The building is about 100 ft. square, and holds four furnace units, each of which consists of six grates or cells, a combustion chamber, an air heater, and a water-tube boiler. To keep the temperature as uniform as practicable, the six cells are divided into two groups of three cells each, and have a combustion chamber between them. Each grate has an area of about 20 sq. ft., and is backed by a drying hearth. Fans drive air through an air heater and then through the ashpit to the fuel on the grate at a temperature of about 300° Fahr., and under a pressure of about 3 in. of water. The gases go through the combustion chambers to the four boilers. These are of the horizontal, water-tube type, each rated at 200 h.p. The clinker drawn from the grate falls through a trap door into a clinker car standing on rails in the basement.

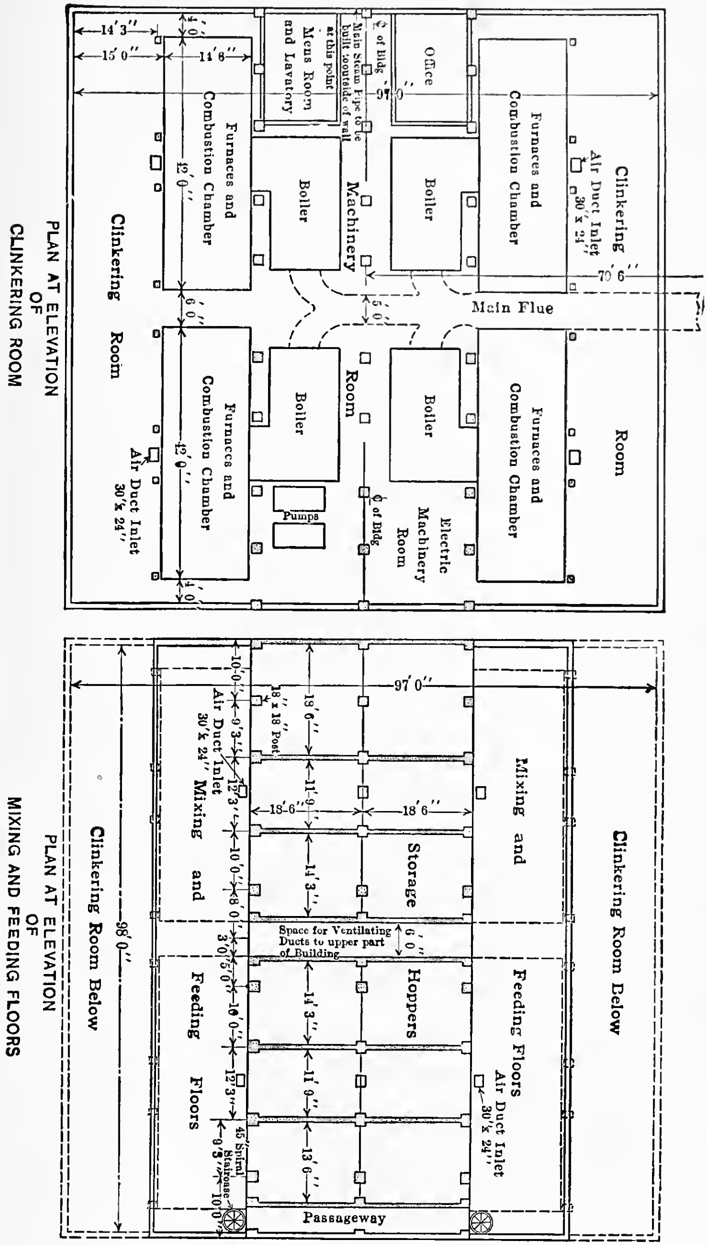


FIG. 98.—General Plans, Milwaukee Incinerator.

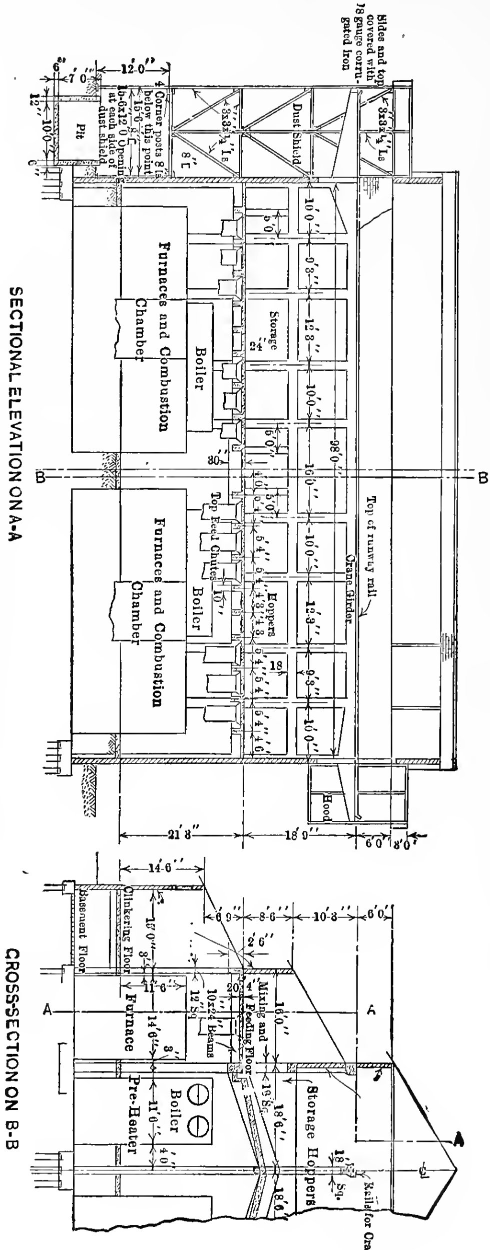


FIG. 99.—Sections, Milwaukee Incinerator.

The garbage, being collected separately, is stored by itself and drained, thus reducing its weight by from 7 to 9%. It is further dried on the drying hearth before being mixed with the rubbish and ashes.

In 1917 the average evaporation was 1.626 lb. of water per pound of mixed refuse. In 1919 it was only 1.315. The power utilization has been quite irregular. It varied in 1917 from 16,884 kw.-hr. for November to 198,249 kw.-hr. for August. No clinker utilization has as yet been attempted, except for filling in at the shore of the lake.

Being the first large incinerator built in America, and with quite limited funds, a number of expediencies and space restrictions were adopted which could readily have been avoided under other conditions. After ten years of service the plant is now in very good condition. Three years ago hydraulic cylinders were put in for the purpose of operating the charging doors. Mr. Samuel A. Greeley was superintendent of the plant for the first fifteen months of operation. He was succeeded by Mr. Joseph E. Roddy, who is still in charge.

4. Berkeley.—The Sterling incinerator at Berkeley (J. J. Jessup, City Engineer), was built in 1913. The plant is housed in a steel and reinforced concrete building having large windows and convenient doorways for access to the refuse-receiving pit and the furnace room.

The incinerator was designed by Hughes and Sterling, and is of the top-feed type with three cells. The material is first fed to a drying hearth behind the grate, and is dragged upon the latter as needed. High-pressure forced draft supplies the air under the fires. Three grates are placed side by side, opening one into the other, with a common combustion chamber at one end in which the temperature is not less than 1200° Fahr. From this chamber to the stack the gases pass over the heating surfaces of an Abendroth-Root water-tube boiler and then through a regenerator of iron and steel tubes set into the flue. The forced draft is supplied by a blower, and the air passes between the heated regenerator tubes, which raise its temperature to above 350°.

The refuse is taken from the dumping pit by a grab-bucket, carried on a monorail crane running on an I-beam in the roof space of the building. The bucket dumps into one of the three steel charging containers, one above each cell. The furnace is charged by hydraulic rams, with valves controlled from the stoking floor.

The guaranties for the plant were: That it shall destroy 48 tons of mixed refuse in twenty-four hours; that the steam generated in the boiler, from and at 212° Fahr., shall not be less than 1 lb. per pound of refuse consumed; that the minimum temperature in the

combustion chamber shall not be less than 1250° Fahr.; and that at least 53 lb. of refuse per square foot of grate area per hour shall be burned.

The performance of the plant during the official test exceeded the guaranties, and during the subsequent operation was quite satisfactory as to complete incineration without offense. However, its use was discontinued for a time, when it was found less expensive to dump all the refuse at sea.

5. Savannah.—Plans and a section of the refuse incinerator at Savannah are shown in Fig. 100. They are described by the Chief Engineer of the city, Mr. Conant.

The incinerator is of the Heenan–Froude type, and was completed in March, 1914. It has a daily capacity of 130 tons, including garbage, rubbish, ashes, and stable sweepings. The plant is built near the city water-works pumping station, and steam from its boilers is carried by a pipe directly to the steam header in the water-works boiler room.

The plant consists of two 65-ton furnaces, and each unit has four cells, about 28 in. wide on the bottom, 34 in. at the top, 16 in. deep, and 8 ft. long. Each unit has a separate combustion chamber of large size, a 200-h.p. Wickes water-tube boiler, an air heater, and a centrifugal fan for supplying forced draft. The cells are fitted with trough grates.

The contract for the plant included the construction of the building in which it is housed, a receiving pit having a capacity of 260 cu. yd., a regenerator or pre-heater, an electric hoist for transferring the refuse from the storage pit to the containers, the necessary instruments for measuring and recording the conditions at the furnaces, and a steam turbo or engine-driven generator of 75 kw. to supply the current for lighting the plant and operating the motor.

Each cell has a grate area of 20 sq. ft., and each boiler a heating surface of 2000 sq. ft. and a working pressure of 160 lb. per square inch. The stack, of radial brick construction, is 150 ft. high and 6½ ft. inside diameter at the top. The receiving storage pit is 32 ft. long, 11 ft. wide, and 20 ft. deep. The refuse is raised by a grab-bucket which can pick it up from any part of the pit without extra handling. A container, in which the material is deposited by the grab-buckets, is placed over each cell. Each has a capacity of about 1 cu. yd., and is closed by horizontal sliding doors, built in two parts. Each cell receives charges of about 1 cu. yd. The space above the grate is common to each cell and to the combustion chamber, so that there is free interchange of heat between the cells. The main grates are of heavy cast iron, and are perforated so as to give proper distribution of air

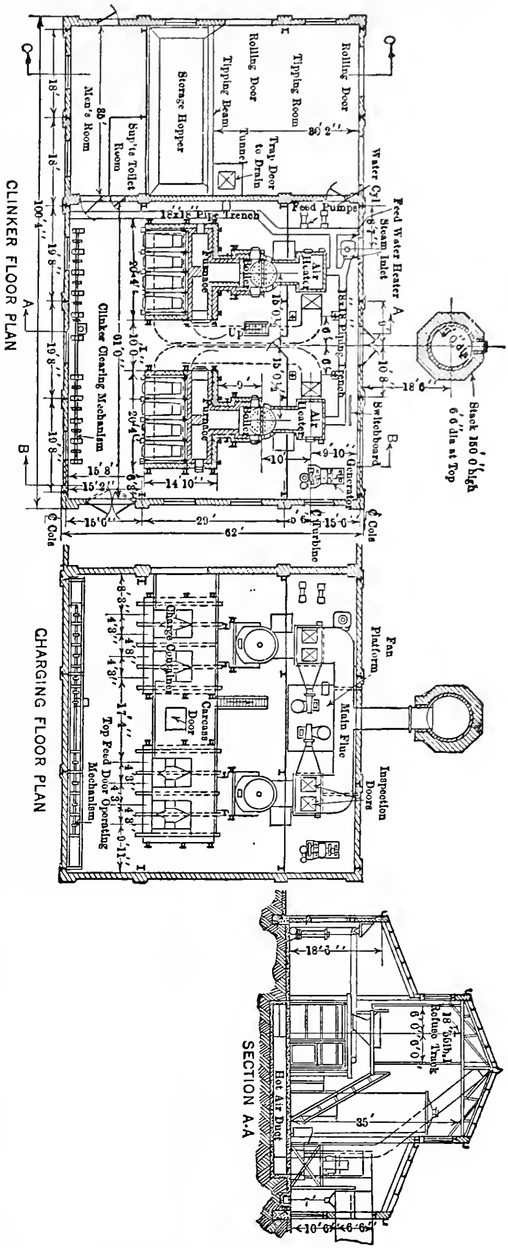


FIG. 100.—Plans and Section, Savannah Incinerator.

throughout the refuse, and, at the same time, secure the maximum cooling effect on the iron supports. The clinker car is of special design.

The superheater is of the Foster type, and the air heater is at the back of the boilers. The air for the forced draft is taken from the ventilating system in the building.

The guaranties for the plant were: That it shall be capable of destroying, under normal operation and without additional fuel, 130 tons of mixed refuse in twenty-four hours; that no obnoxious gases shall escape from the chimney or the building; that at no time, during normal operation, shall the temperature fall below 1250° Fahr.; that an average temperature of 1500° Fahr. shall be maintained in the combustion chambers; that the steam generated in the boilers, from and at 212° Fahr., shall not be less than 1.3 lb. per pound of refuse consumed; and that the net effective boiler capacity for steam utilization, over and above that required for operating the plant, shall be 330 h.p., based on 34.5 lb. per boiler horsepower.

The cost for incineration under the stated conditions was not to be more than 40.4 cents per ton. The refuse to be burned per hour per square foot of grate surface was not to be less than 68 lb.

The official test shows that all the guaranties were fulfilled. The total cost of the plant was about $125,000. Regarding the operation, Mr. Conant says:

"All the refuse brought to the plant is weighed and then dumped into the storage hopper at the ground level. It is taken from the hopper by a grab-bucket operated by an electric transporter, and delivered to the containers, one of which is located over each cell of the furnace. At the bottom of the containers is a solid door, operated hydraulically, the operating of which is done on the stoking floor, which enables the stokers to fill their grates in accordance with the requirements of their fires.

"Stoking is done through a supplementary door, which avoids the necessity of opening the large door through which the clinker is withdrawn.

"The clinker formed on the grate is removed by semi-mechanical means. The sides of the grates diverge slightly from the rear to the stoking door. There is a large bar to which is fastened a plate which forms an upturned hoe laid on the bottom of the grate before the first charge is dropped upon it, and the clinker is pulled out bodily by power obtained from a hydraulically-driven winch onto a hand-pushed car, which is pulled over a level, paved surface to the dump. This method of clinkering permits of the clinker being removed from the grates within from three to four minutes. The platform at the dump is on the same level as the stoking floor, the clinker is dropped upon a sheet-iron platform, and is scraped into wagons or carts and hauled away. While withdrawing the clinker, regulating valves are operated so as to shut off the air supply from the air heater.

"One great advantage of the furnaces at this plant, over furnaces constructed at some other cities, is that a deep fire is maintained, which enables the wet portion of the refuse to be more thoroughly dried and destroyed than on shallow grates. In my opinion, the success of this plant is partly due to this particular feature.

"The average time of burning a charge is twenty minutes. Usually six charges are made for each clinker produced on the grates. When the plant is working at its full, or nearly full, capacity, the labor required is operated in three shifts of eight hours each. With the destruction of from 60 to 75 tons of garbage, only one unit is used with three shifts of labor. This is better than to use two shifts, working both furnaces, for a more even supply of steam is delivered to the pumping station.

"During July and August, when the delivery of watermelon rinds averages 20 tons daily, this amount of extra wet garbage, bringing the percentage of moisture above the guaranty, is only destroyed by adding dry material which has sufficient heat units to offset the excessive moisture in the garbage. This is brought about by adding 10% in weight of cinders collected from manufacturing plants. With the addition of these cinders complete combustion of the garbage is obtained."

6. Ridgewood.—A Decarie incinerator for Queens Borough, New York City, was built at Ridgewood and put in operation in April, 1916. There are two 50-ton units, which may be operated separately or together. The furnaces are housed in a brick building having reinforced concrete floors and a roof of Spanish tiles. The chimney is of radial brick construction, and is 6 ft. in diameter and 150 ft. high.

A special feature of the plant is the absence of any storage bins. All material to be burned is dumped on the upper floor, and passes to the furnaces through hopper openings. Each unit is capable of holding 16 cu. yd. of garbage and rubbish at one time, without tending in any way to smother the fires. This is made possible by the basket-grate construction, a marked feature of the Decarie design.

Each unit has its gas-combustion chamber, pre-heater, and both induced- and forced-draft fans. The fans for the induced-draft are No. 8 Sirocco, and those for the forced draft are No. 110 Special, both made by the American Blower Company. All fans are driven by steam engines, the steam being generated in the water jackets of the furnaces by the burning refuse.

All materials were to be consumed to a mineral ash practically free from organic matter, and the plant in its operation was to cause no nuisance through the escape of obnoxious odors, gases, or dust from either the building or the stack. The results of the official test are shown in Table 122 (under Tests).

In the test, the plant exceeded its rated capacity by from 48 to 56% with units operating separately, and by 38.5% when both units

were working, burning as much as 72.4 lb. of refuse per square foot of grate area per hour, without any fuel or domestic ashes to help maintain the temperature.

Analyses of the gases when leaving the stack showed an average of about 6 to 8% of carbon dioxide, an excess of free oxygen of about 16% (due, of course, to the forced draft), together with a trace of sulphur dioxide. There was no carbon monoxide or hydrogen sulphide present. There was no dark smoke.

The average temperatures in the gas-combustion chambers show that this plant occupies a position between the high-temperature and the slow-burning low-temperature types. The temperature in the furnace proper was high, and the tin cans, bottles, crockery, etc., were fused into a vitreous clinker. The hot forced draft was essential in obtaining these results, and saved the addition of fuel which otherwise would have been necessary. The plant was built by Kelly and Kelly, of Long Island City, for $98,700, and the machinery was furnished and set up by the Decarie Incinerator Company, of Minneapolis.

7. Topeka.—The following description of the garbage furnace at Topeka was prepared by its designer, Mr. S. R. Lewis. It should be classed as a low-temperature furnace.

"The garbage and refuse furnace at Topeka was built in 1909. It is the first plant of the Lewis type.

"There are two furnaces, back to back, each having three grate units. The furnaces are heavily braced with vertical pairs of 6-in. I-beams and horizontal channels opposite the skewbacks of all arches. In addition, all the walls are of 9 in. of fire-brick backed with 9 in. of common brick, and are sheathed in an air-tight steel casing to prevent air infiltration.

"Each grate unit has a shaking grate and a hearth sloping at 45°, the area of each hearth being approximately three times that of the grate.

"The garbage and refuse (the plant is not intended to handle ashes) are dumped directly from the wagons into tight, steel bins, from the second floor level, reached by an inclined driveway. Considerable material is brought by merchants of the city in their own conveyances. Each bin holds about 1½ cu. yd. In the bottom of each bin is a sliding piston having a reciprocating motion, and about ten strokes are required to force the refuse in a thin sheet, through the automatic fire door, at the furnace end of each bin, into the furnace.

"The refuse falls at the top of the inclined arched hearth, and, without appreciable hand stoking, slowly rolls or slides down the incline. As the inclined arched hearth is but 30 in. from the parallel reverberatory arch above it, and as all the products of combustion must pass through this space, the incoming material is warmed and to a large extent burned before it reaches the grate. As the charging doors are generally closed when the feeding mechanism is in operation, and in any event the door to the furnace from the storage bin

is obstructed by refuse until the bin is nearly empty, the feeding of refuse may be said to be carried on through an air lock.

"The three furnaces on each side are in series, so that the heat effect is cumulative, and, on this account, the unit nearest the chimney has proved to have considerably more burning capacity than the unit farthest away from it. As no ashes are burned, there is little clinker as a result of the combustion, and the shaking grates have proved satisfactory. They must be of a type, however, not easily clogged by molten glass or metal.

"The furnace is operated on the continuous, rather than the charge, principle. The refuse is constantly entering, without undue air leakage, and the temperature, boosted by added fuel, is easily held constant.

"After passing over the third hearth, the gases dive down into a very large combustion chamber, leaving it for the chimney near the floor. This chamber has 16 times the cross-sectional area of the chimney, and has been found quite satisfactory as a dust arrester.

"An eight-hour test run, with a calibrated electric pyrometer in the combustion chamber, 16 ft. beyond the last grate unit, showed an average temperature of 1350°. It was necessary to burn about 120 lb. of coal per ton of mixed refuse, to maintain this temperature. With wet garbage exclusively, it has been found necessary to burn as much as 225 lb. of coal per ton of garbage to maintain 1200° Fahr. in the combustion chamber.

"To show the importance of the air lock and continuous slow-feeding, repeated tests have been made, using the charging principle common to furnaces of older design, through emergency direct hoppers, which are always provided. Instead of a constant temperature of around 1400°, the combustion chamber pyrometer showed an immediate drop to 900° or lower when the hopper was opened, and a slow recovery while the charge of cold, wet material was absorbing heat from the furnace walls and from the fire.

"The increase in the life of the furnace over older types is notable. After four years' run, there was no appreciable depreciation, except around the doors, and an expenditure of a trifling sum covered the repairs needed. The sudden and wide variations in temperature, inevitable when charging through open hoppers, as done in a chimney-draft furnace, are eliminated. The hearth, with its steep slope, heated on one side only, and built of brick rather than blocks, bids fair to last as long as the furnace.

"The Topeka plant is in a park, near the business center of the city, and is housed in a substantial brick building. The plant is rated to burn 6000 lb. of refuse per hour."

This plant has been closed.

8. Minneapolis.—The garbage and some of the refuse of Minneapolis are burned in a garbage furnace built by the Decarie Incinerator Company. The furnace is designed to burn garbage and rubbish, with the addition of coal when required, but is not suitable for burning ashes in large quantities. The plant stands on a large open piece of ground, and has been operated with fair success under the supervision of Dr. Hall, Superintendent of the Health Department.

9. Miami.—This rapidly growing city has a plant burning garbage and rubbish. However, it is not of sufficient capacity for the needs of the city, and has to be operated at a very high rate of combustion, which compels the use of about $1\frac{1}{2}$ cords of wood per day, in addition to the rubbish. Under these conditions, the cost of operation per ton is greater than it would be if the capacity were greater.

Under the supervision of Mr. C. W. Murray, the City Engineer, the operation has been conducted with special intelligence and care, so that, even under unfavorable conditions, there have been no complaints of objectionable odors. It is intended soon to enlarge the plant, the extensions being built on improved designs.

The cost has been:

$1\frac{1}{2}$ cords of wood at...........	$7.00	$10.50
20 laborers at................	3.00	60.00
1 foreman at................	5.00	5.00
		$75.00

Cost per ton, $1.68.

10. Nye Incinerator.—This is one of the latest furnaces offered for burning garbage and rubbish without ashes. It is comparatively simple and operates somewhat on the Dutch oven principle. It is practically square, and is arranged to receive separately dry and wet refuse in a single large compartment. The refuse is dumped through two openings at the top and is burned on a concrete floor. One opening receives the dry material, such as rubbish or trash, which drops through a chute immediately to the grate; the other receives the wet garbage, including watermelon rinds, night-soil, and small dead animals. This latter material drops on a shallow pan where its surplus moisture is evaporated. The dried material is finally burned with the rubbish into which it has been raked.

The furnace is lined with fire-brick to retain the heat and reflect it on the refuse. To conserve the heat, there is an automatic arrangement for pre-heating the air supplied to the ashpit under the grate. This pre-heating is accomplished by passing fresh air through flues below the concrete floor and then behind the side-walls of the furnace. A combustion chamber is provided where the gases from the different parts of the furnace floor are united and burned, and where a temperature of 1500° has been reached. From this chamber the gases are brought back through flues under the wet garbage pan before they escape through the stack.

Care must be taken to have each kind of refuse uniformly mixed before it is dumped into the openings, as otherwise great fluctuations

in temperature will result, the lower temperatures being insufficient for thorough combustion, and resulting in odors of the fumes and smoke escaping from the stack.

No attempt has been made to utilize the heat for generating steam at these furnaces. It is said that, ordinarily, no extra commercial fuel is used, as the heat of the burning rubbish is sufficient to drive the moisture from the wet garbage. But in some of the plants the the combustion produces insufficient heat for the odorless incineration of the whole.

As such incinerators are not usually operated continuously, it is necessary to start the fires frequently. For this purpose, either selected rubbish which, when burned, will not produce offensive odors must be used, or specially supplied fuel.

Incinerators of this type are in operation in Jacksonville, Fla., Chattanooga, Tenn., Brunswick, Ga., Anniston, Ala., Norfolk, Va., Pelham Bay Naval Base, N. Y., and other places.

11. U. S. Army Cantonments.—Incinerators of various sizes and types, ranging from small hospital or kitchen types to units having rated capacities of 50 tons per twenty-four hours, were built at various Army posts and Cantonments. Their purpose was to provide a place for the complete and sanitary disposal by incineration of any waste matter containing disease germs, together with rubbish and such portions of the garbage and manure as could not be disposed of by sale.

These incinerators were intended to have sufficient capacity to dispose of the entire output of garbage and refuse produced each day, which was estimated at from 1.5 to 2.0 lb. per man per twenty-four hours.

The larger incinerators consisted of a suitable transfer platform for receiving the cans from the various parts of the camp, the can-washing equipment, and the incinerator proper, with appropriate fire-proof buildings for the permanent camps. The incinerators were built of different designs, in accordance with the various contractors' proposals, but were generally of the garbage furnace type, comprising one or more grates set in brickwork and encased entirely in reinforced concrete. A grate for burning coal or other additional fuel, and a large opening for dead animals were also included.

At most of the Army Cantonments the garbage proper was sold to contractors for hog feeding, and the incinerators were used for rubbish burning.

12. Montreal.—A British refuse incinerator, or destructor, was built in Montreal in 1894. Mr. Charles Thackeray erected a plant which was a slight modification of the Fryer design, placing the cells back to back, and with a common charging platform on top. The

fire grates are inclined and rocking in order to move the refuse forward. About 1912 it was determined to separate most of the ashes from the rest of the refuse and dump them separately at near-by points. The reason given was the insufficient size of the incinerator. Sifting through a fine-mesh screen had been tried, in order to reduce the quantity, but it was soon found that this was too expensive to make it worth while, and that in damp weather the siftings became foul. In summer 120 tons and in winter 70 tons were incinerated per day.

13. Westmount.—The first successful British refuse incinerator, or destructor, in America, was erected at Westmount, in 1906, and was of the " Meldrum top-feed " type. It consisted of three grates, having a total area of 75 sq. ft., a combustion chamber, a Babcock and Wilcox water-tube boiler having 2197 sq. ft. of heating surface, and a regenerator. The steam is fully utilized, in connection with the combined electric plant, for operating the works and illuminating the town.

The buildings are of brick, and the chimney, of the Custodis type, is 150 ft. high. The plant is in a central location, and has a very favorable site, as the refuse is delivered to the storage hoppers at an elevation which permits it to pass through the furnaces to the clinkering floor by gravity. See Fig. 101.

Forced draft is provided by steam-jet blowers, and the figures of the official test show that very good results have been obtained.

In March, 1910, an extension or duplicate plant was added, increasing the capacity by 50 tons per twenty-four hours. This is of the Heenan top-feed type, and consists of three grates (75 sq. ft.), a combustion chamber, a Babcock and Wilcox water-tube boiler having a heating surface of 2197 sq. ft., a superheater, and a regenerator. The forced draft is obtained with a centrifugal fan, 66 in. in diameter, coupled directly to an enclosed, vertical, high-speed engine.

The following guaranties were given:

1. That the plant shall be capable of burning, to a hard innocuous clinker, 50 tons of refuse per day of twenty-four hours, or 20 tons in ten hours.

2. That the combustion of the refuse shall be complete, and free from nuisance, and that no odors or noxious gases shall be emitted from the chimney.

3. That the temperature in the combustion chamber, in normal working, with refuse of average quality, shall not fall below 1500° Fahr., and that the average temperature shall be from 1700 to 1800° Fahr.

4. That, with refuse of average quality, an evaporation of $1\frac{1}{4}$ lb. of water per pound of refuse, from and at 212° Fahr., shall be obtained.

FIG. 101.—Westmount Incinerator and Electric Light Plant.

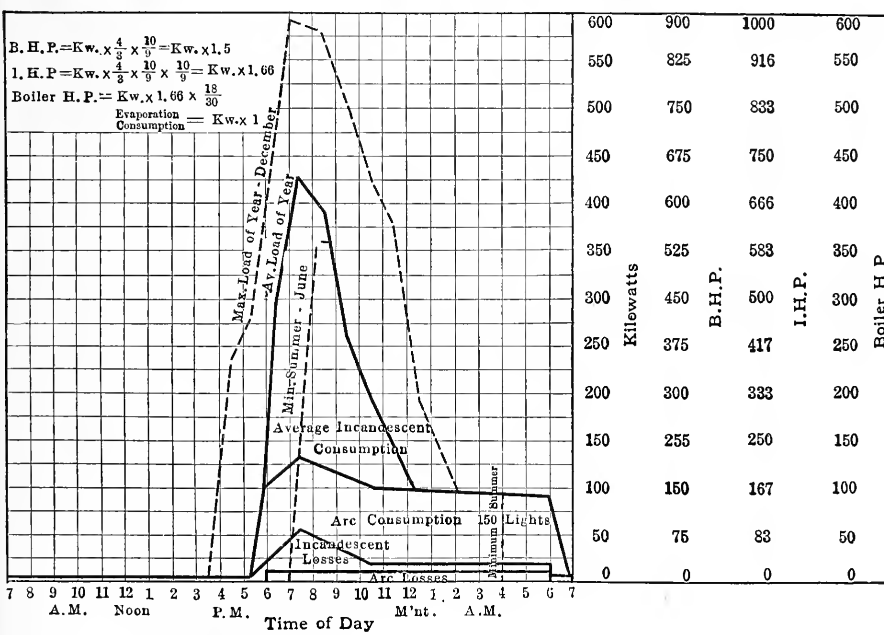


FIG. 102.—Daily Output Curves, Westmount Incinerator.

The official tests proved that the guaranties were fully met, and the incinerator has remained in successful and economical operation.

The clinker and ashes are taken away, at no cost to the city, and utilized for roads, concrete basement floors, and for making concrete building blocks.

Fig. 102 gives the daily output curves recorded by Messrs. Ross and Holgate, engineers, in 1905. For each hour from afternoon until morning there are given curves for 150 arc lights, the maximum (winter) and the minimum (summer) incandescent lights. The deficiency of power obtained from the incinerator, when it occurs, is supplied from coal-fired boilers. The total capital account of the incinerator plant is $106,061.76.

During the fiscal year 1918–19 there were consumed 8032 tons of garbage and rubbish and 10,627 tons of ashes. From this consumption a credit of $4872.46 was given for heat value on the year's cost of operating the plant.

The following statement is taken from the annual report of Mr. Geo. W. Thompson, General Manager, for the year ending October 31, 1919.

Revenue and Expenditure at the Refuse Incinerator at Westmount, Que.

For 12 months ending October 31, 1919.

Revenue

Fuel value of refuse consumed and charged to electric light operations		$4,872.46	
Interest earned		981.33	
		$ 5,853.79	
Health Department, for destruction of refuse		19,464.52	
			$25,318.31

Expenditure

Operating expenses		$14,998.34	
Operating ash dump		1,380.21	
		$16,378.55	
Interest on debentures	$4323.59		
Sinking fund for redemption of bonds	1060.62		
Loss on sale of bonds	53.78		
		$5,437.99	
Reserve for depreciation		3,501.77	
			$25,318.31

As 19,707 tons of refuse were collected, the actual cost of incinerating one ton was $1.28.

14. Vancouver.—A Heenan and Froude incinerator of 40 tons capacity was built in Vancouver (population, 60,000) in 1907. The refuse burned contained 46% garbage and market waste, 40% ashes, and 12% trade refuse. It has one unit of three cells, combustion chamber, fan draft, and pre-heated air, a 65-h.p. Babcock and Wilcox boiler, a chimney 120 ft. high, back feed, and clinkering from the front. The power is used for operating and lighting the works, and there are also some lights supplied outside.

The refuse burned per man-hour was 1.04 tons (6 men eight hours each).

The clinker was one-third of the refuse delivered, hard and well burned. The temperature in the combustion chamber was from 1500 to 2000° Fahr. The temperature of the forced draft was from 511 to 600° Fahr. The evaporation reported was 0.52 lb. of water per pound of refuse. No nuisance was caused about the plant.

15. Toronto.—The incinerator at Toronto was built in 1912 under the supervision of I. S. Osborn. It has a guaranteed capacity of 180 tons per day of twenty-four hours, there being three furnaces in operation. In the official capacity test the results exceeded the guaranty by 33%. The plant is now operated with one shift daily, and the capacity of the three furnaces is from 600 to 675 tons per week of 5½ days.

The operating expenses have been reduced recently, due principally to changes in the furnace and container doors, which were first operated by water pressure and are now operated by compressed air. Three extensions of the tipping floor have recently been built, and have also caused a material reduction in the cost of operation.

16. Watford, England.—Goodrich states * that the Meldrum destructor at Watford—about 17 miles north of London—combined with the sewage pumping plant, is one of the most successful in Great Britain. (See Fig. 103.) The furnace is a front-feed regenerative destructor, and consumes about 27 tons of refuse daily, working continuously for about 150 hours per week. Steam, at a pressure of 120 lb. per square inch, is supplied to Worthington pumps and air compressor engines. About 1,000,000 gal. of sewage are pumped per twenty-four hours to a height of 8.4 ft., and an additional 500,000 gal. are pumped by the air compressors and ejector plant.

The destructor was started on March 31, 1904, and the following figures,† covering the first two years of working, Goodrich states, "are perhaps without parallel among combined works of the kind:"

* In "The Collection and Disposal of Municipal Waste," by W. F. Morse.

†For the convenience of American readers, the English figures have been converted into American, taking the English pound sterling as equal to $4.86⅔.

For year ending:

March 31, 1904.	Before erection of destructor	$4592.33
March 31, 1905.	After erection of destructor	774.87
March 31, 1906.	After erection of destructor	1146.73
First year's working of destructor, saving in coal bill		3815.02
Add revenue from sale of clinker		493.66
Add revenue from sale of old tins		39.50
Second year's working of destructor, saving in coal bill		3445.60
Add revenue from sale of clinker and residuals		984.65
Total saving for two years		$8778.43
Total cost of repairs and maintenance		82.49

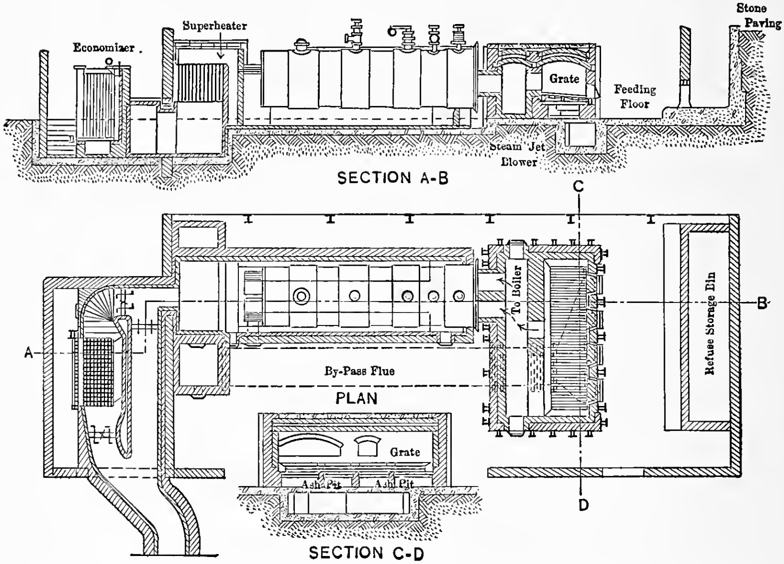


Fig. 103.—Plan and Sections of Meldrum Destructor, Watford, England. (From "The Collection and Disposal of Municipal Waste," by W. F. Morse.)

The general arrangement of the plant is shown in Fig. 103. The hot gases, after passing the boiler, are utilized for heating the air for combustion in a Meldrum regenerator, and also for heating the boiler feed-water in a Green's economizer, the temperatures being about 300 and 250° Fahr., respectively, the heating surfaces of the boiler regenerator and economizer reducing the temperature of the gases from an average of 1800° Fahr., in the combustion chamber before the boiler, to about 400° Fahr. at the chimney base.

The steam-pressure recorder diagrams show a very steady pressure throughout the twenty-four hours.

17. St. Albans, England.—The Heenan destructor at St. Albans is an excellent example of a well-designed plant of the front-feed type. There are two 3-grate units with combustion chambers, and two Babcock and Wilcox boilers, having a heating surface of about 2000 sq. ft., and fitted with Foster superheaters.

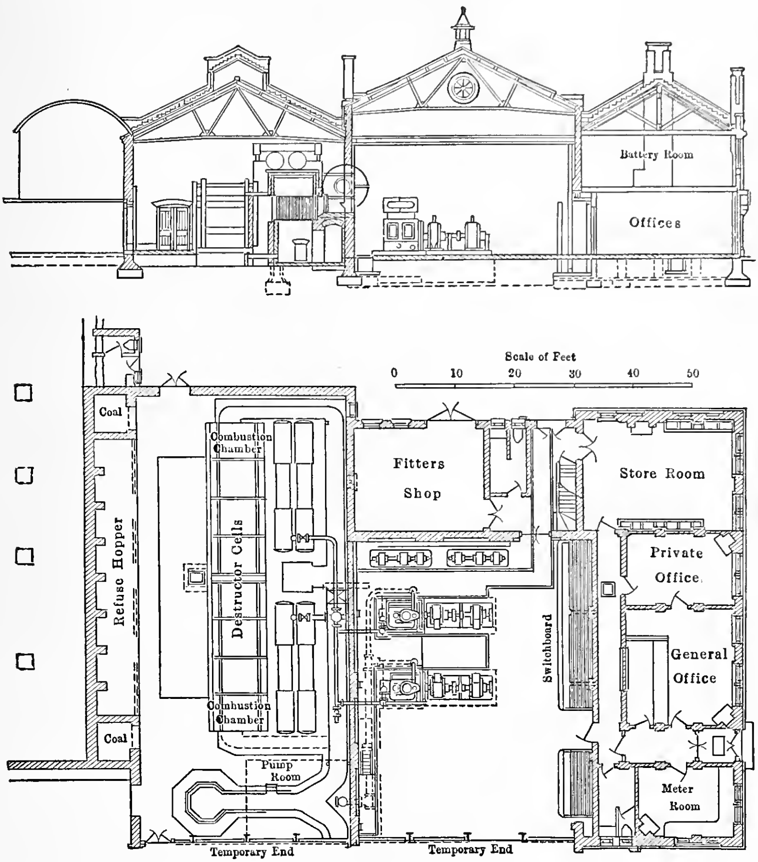


FIG. 104.—Plan and Section of St. Albans Destructor.
(From "Modern Destructor Practice," by W. F. Goodrich.)

The fan for the forced draft may be driven by the usual high-speed engine or by a motor of the variable-speed type, with shunt regulator. Regenerators heat the air for combustion. The chimney is 130 ft. high, and has an internal diameter of $5\frac{1}{2}$ ft. at the top.

Fig. 104 shows a plan and section of the plant, from which it is seen that the building is arranged in three main bays. The rear bay

contains the destructor, boilers, and pumping plant; the generating sets, switchboard, and fitters' shop are in the center; and the front bay houses the battery-room, test-room, store-room, offices, etc. The whole plant is arranged so that its capacity may be doubled at any time without building another chimney.

18. Coventry, England.—The Heenan destructor at Coventry consists of three back-feed, hand-fired and clinkered units, each complete and independent. Each unit comprises a continuous furnace divided into three sections or grates by division walls in the ashpit. The products of combustion pass from the furnace into the combustion chamber, the functions of which are to permit a deposit of the dust carried from the furnace, and to ensure the complete diffusion and mixing of the gases before they come into contact with the boiler. During four separate tests, each extending over four days, the average temperatures varied from 1840 to 2587° Fahr.

The gases from the combustion chamber pass through a Babcock and Wilcox water-tube boiler, having 1966 sq. ft. of heating surface, and constructed for a regular working pressure of 200 lb. per square inch. Each boiler has a Foster standard superheater, which delivers the steam at the generating station main, 300 ft. distant, with a superheat of 100° Fahr.

An air heater, or regenerator, is placed in the path of the gases after these have passed through the boiler, the object of which is to raise the temperature of the air, required for supporting combustion, by passing it over the exterior of the tubes of the heater while the hot gases pass through them. In this way the temperature of the air extracted from the destructor house, which is normally about 68° Fahr., is raised to an average of about 300° Fahr., and this, being delivered at the under side of the furnace bars, accelerates the ignition of freshly charged material and raises the furnace temperatures.

From the air heater the gases pass through a Green's economizer and thence to the chimney. Each economizer consists of 96 pipes, with suitable scraper gear. Thus each destructor unit is complete and independent, and is equipped with all the steam raising accessories that make a plant efficient.

The furnaces, combustion chambers, boiler settings, and flues are lined with Stourbridge fire-bricks, and the exterior walls are faced with salt-glazed bricks.

The air for the forced draft is extracted from the interior of the destructor house by an air duct placed in the apex of the roof, extending the whole length of the building. Openings in this duct admit the air from the destructor house, and it is drawn through the ducts by centrifugal fans. This has the advantage of removing effectively

all foul air from the main building and hoppers, the air being delivered to the ashpits at a pressure of about 2 in. of water column. There is absolute control of this air supply, and it can be regulated in accordance with the requirements of each furnace, or it can be cut off entirely from any grate section during the clinkering operation.

The refuse, on arrival at the plant, is taken up an inclined roadway, and is tipped into the receiving hopper. The storage capacity is sufficient for one day's supply, and, as the Coventry refuse when fresh is not objectionable, the arrangement has fulfilled every requirement.

From the hopper the refuse falls to the level of the charging sill, and thence is shovel-fed into the furnace. The firing doors are 2 ft. 6 in. above the floor level, so that the labor of feeding is reduced to a minimum for a hand-fired plant.

Owing to the relative levels of the destructor site and certain neighboring residential areas, it was considered desirable to erect a chimney shaft 180 ft. high, so as to avoid the possibility of creating any nuisance. The products of combustion issuing from this chimney are, at almost all times, scarcely visible.

The whole plant is contained within the main building, which is a plain brick structure with glass and slate roof. The whole building is of fire-resisting materials. A mess room, bath room, and dressing rooms are provided for the workmen. A portion of the main building is enclosed to accommodate the fans, engines, boiler feed pumps, etc., and the clinker utilization machinery is housed in another section. The whole is lighted by electricity.

Fig. 105 shows the refuse destructor plant at Coventry, and Fig. 106 is a view of the clinkering floor. The grinding mill and flag press are shown in Fig. 107.

Fig. 108 is a set of three diagrams* showing the seasonal variation in the combustible content of the refuse of Coventry, and is based on a three years' average of the records of the destructor.

The system of recording all the conditions and work done at this plant was very complete. Every load of refuse was weighed. The water evaporated is drawn from the hot well and delivered to a 2000-gal. supply tank over the pump room. The water drawn from the tank is metered, the meter is read every fifteen minutes, and the results are compared, with the object of ensuring a constant evaporation rate. The steam pressure is taken continuously on a Bristol self-recording gauge. The residue from the furnaces is utilized in various ways. All information, with temperature readings, is entered on the daily log.

* From a paper, by Mr. J. Eric Swindlehurst, entitled "The Construction and Working of a Modern Refuse Destructor."

In order to show the results concisely, the diagrams are based on an average of three years' work. The first chart on the diagram shows the number of tons of refuse burnt during each month. The monthly quantities vary considerably.

The second chart shows that the calorific value of the refuse also varies in marked degree owing to seasonal and other influences.

The evaporative rate is shown on the third chart of the diagram. In this the average evaporation rate is reduced to the usual standard

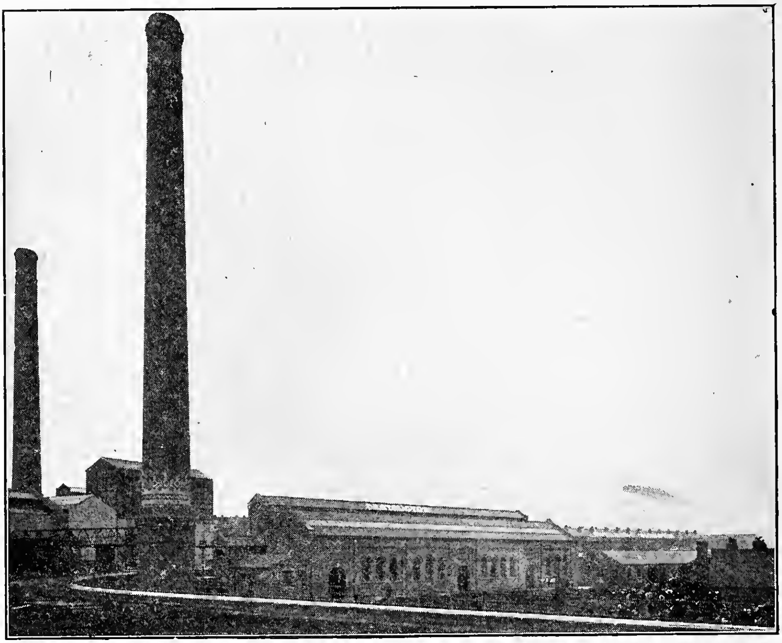


Fig. 105.—View of Refuse Destructor, Coventry, England.

of the equivalent evaporation, from and at 212° Fahr., per pound of combustible. This chart shows that the average evaporation (for three years, as before) has equaled 2.12 lb. of water per pound of refuse burned.

19. Greenock, Scotland.—The destructor at Greenock, a plan of which is shown in Fig. 82, is of the Horsfall, "tub-fed" type, with six cells. Steam is generated in three boilers, of the Babcock and Wilcox marine type, there being one boiler for each pair of cells. The boilers work at a pressure of 200 lb. per square inch, and have superheaters, the final heat of the steam after leaving the superheaters

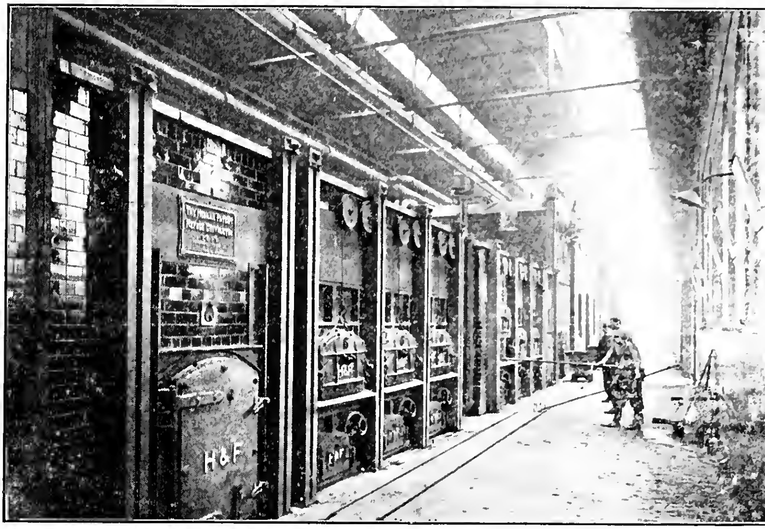


FIG. 106.—Clinkering Floor of Destructor, Coventry, England.

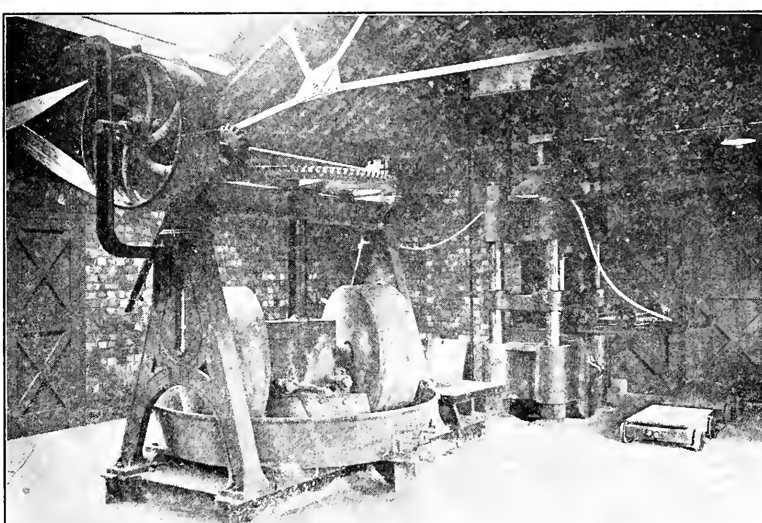
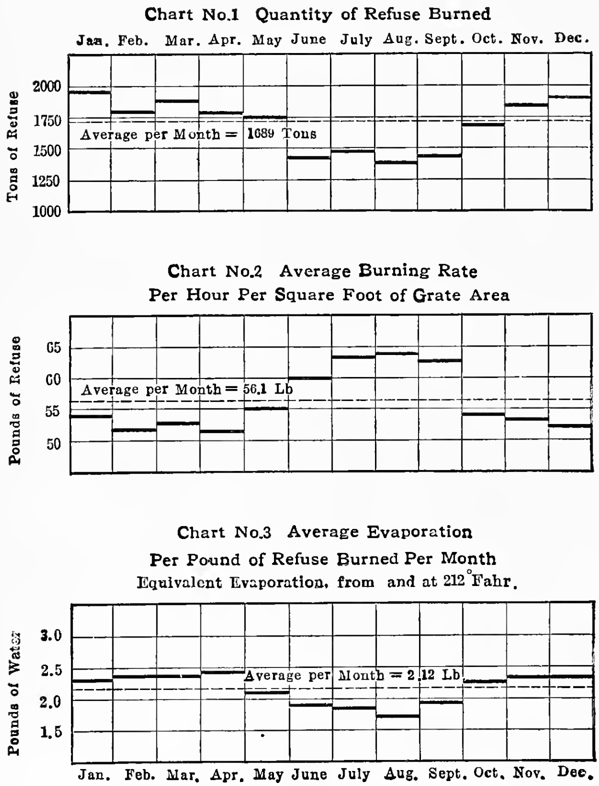


FIG. 107.—Grinding Mill and Flag Press of Destructor, Coventry, England.

being 550° Fahr. The boiler feed-water is heated by a large economizer.

The steam is fully utilized in the generating station with which the destructor is combined. The refuse is a mixture of garbage, ashes, rubbish, and manure, and is of average quality. About 57 tons are burned daily.



Proportionate Quantity of Refuse in Each Month

The Monthly average for the Year being 100

Then:

January	=	117.5
February	=	106.5
March	=	112.2
April	=	105.6
May	=	104.3
June	=	83.3
July	=	87.7
August	=	80.9
September	=	85.3
October	=	99.3
November	=	107.4
December	=	110.6

Fig. 108.—Results Obtained at Coventry, Based on Average of Three Years.

This destructor is mechanically charged (Figs. 80 and 81) and, during 1909, developed an average of 67.2 kw.-hr. per ton of refuse burned. At this plant a temperature of from 1300° to 2160° Fahr. is given as typical of a day's run. The electric power generated netted about $8000 for the year, and the clinker brought about $300.

20. Hamburg, Germany.—The plant was designed by F. Andreas Meyer, City Engineer, and is the largest in Europe. It has thirty-six

cells, with 900 sq. ft. of grate surface, and serves a population of more than 300,000 persons. It can incinerate more than 300 tons of mixed refuse per day. The furnaces are of the single-cell type, and are charged by a top-feed device. (See also under C. 2. Hamburg). The single charge is one meter deep, and is burned to a hard clinker in about thirty minutes, with a forced draft of about 7 in. of water pressure. The highest temperature is ordinarily 1436°, the lowest, 842°, and the average, 1124° Fahr. A special elevated dust catcher is provided for each cell, with a gravity outlet into dumping cars. From 40 to 45% of the refuse is consumed, and, of the residue, from 10 to 12% is ashes and from 50 to 43% is clinker. Clinkering is done by hand through a side opening in each cell.

The thirty-six cells are in six groups, placed in two rows, with the cells back to back. They are all top-fed. A laborer pulls the refuse from the drying hearth to the grate and spreads it out there in thin layers. Every 1½ hours the clinkers are drawn out into trucks and taken outside. The forced draft is shut off when feeding or clinkering is done. Every twelve hours ashes are removed from beneath the grate. The gases pass through a combustion chamber and main flue, which is cleared of dust every three months. Careful tests were made with steam-jet blast and dry-air blast, with the result that the former was effective in greater heat production only when the fire was at white heat. As it is frequently not so hot, the steam then had a relatively cooling effect on the fire. The steam blast, therefore, was abandoned, and the more economical hot-air draft was introduced at a pressure of 1.4 in. and 0.5 in. of vacuum in the main flue.

The average steam production from 1 lb. of refuse is 0.526 lb.

The boilers generated steam at 90 lb. pressure, which was utilized to produce electricity for operating the cranes, ventilators, forced-draft blowers, cinder crushers, and the illumination of the entire plant. Also storage batteries were loaded with the surplus energy, which was about 200 h.p. daily. This was utilized first for sewage pumps, and a city tugboat, and later for the electric trucks collecting the refuse.

In 1901 the cost of incinerating one ton of refuse, including fixed charges for depreciation and interest, was 1.046 marks, or about 25 cents. The cost of collection was 2.031 marks, or about 50 cents per ton.

Dr. Lenormand, Municipal Counselor of Le Havre, France, in his Report on the Treatment of Municipal Refuse of Le Havre, ("Rapport sur Traitement des Ordures Ménagères"), 1908, in speaking of refuse collection and disposal in Hamburg, says:

"Sans doute, nos mœurs françaises s'accommoderaient mal d'une semblable organisation, d'allure toute militaire; il n'en faut pas moins convenir que la

grande ville allemande est d'une propriété merveilleuse et qu'elle ne doit pas être loin de deténir le record parmi les capitales du monde entier."

Figs. 109, 110, and 111, illustrate this incinerator.

21. Paris, France.—For centuries Paris has been bargeing or carting its refuse outside of the city for dumping. During the last century several efforts were made to pulverize it and produce manure. Sorting was also tried, and finally, in 1894, a trial furnace was built at Vitry to test the merits of incineration, substantially according to

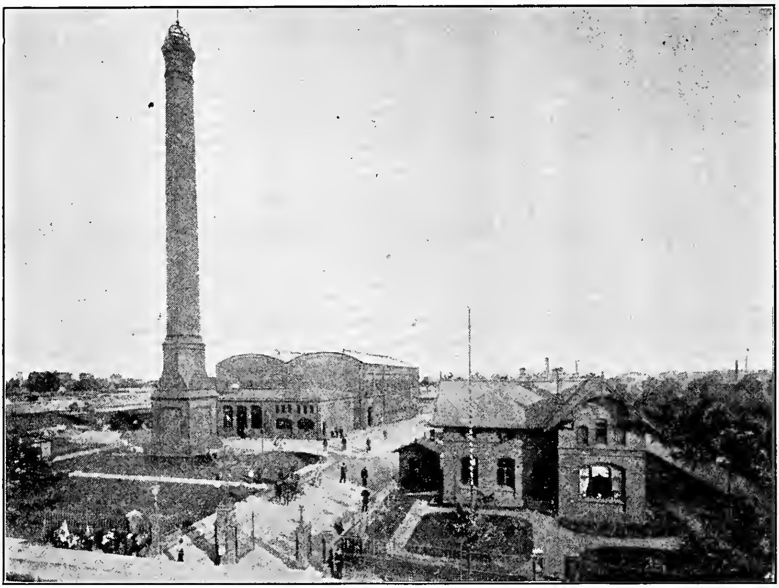


FIG. 109.—View of Hamburg Incinerator.

the Horsfall system. The grate was 2 meters wide, $1\frac{1}{2}$ meters deep, and inclined 23°. The drying hearth was 1.8 meters long. The chimney was 1 meter in diameter and 31 meters high. The temperature above the fire averaged 1030° Fahr. In the warm season the residue weighed about 32% of the original refuse, and measured about 19% of its bulk. In cold weather these figures were, respectively, 40% and 34% (see also Chapter I). As a result of this test, incineration was not then introduced.

In many cities of France it was thought that the solution of the problem should be a combination of pulverizing some of the organic matter and incinerating the rest, believing that the refuse had suf-

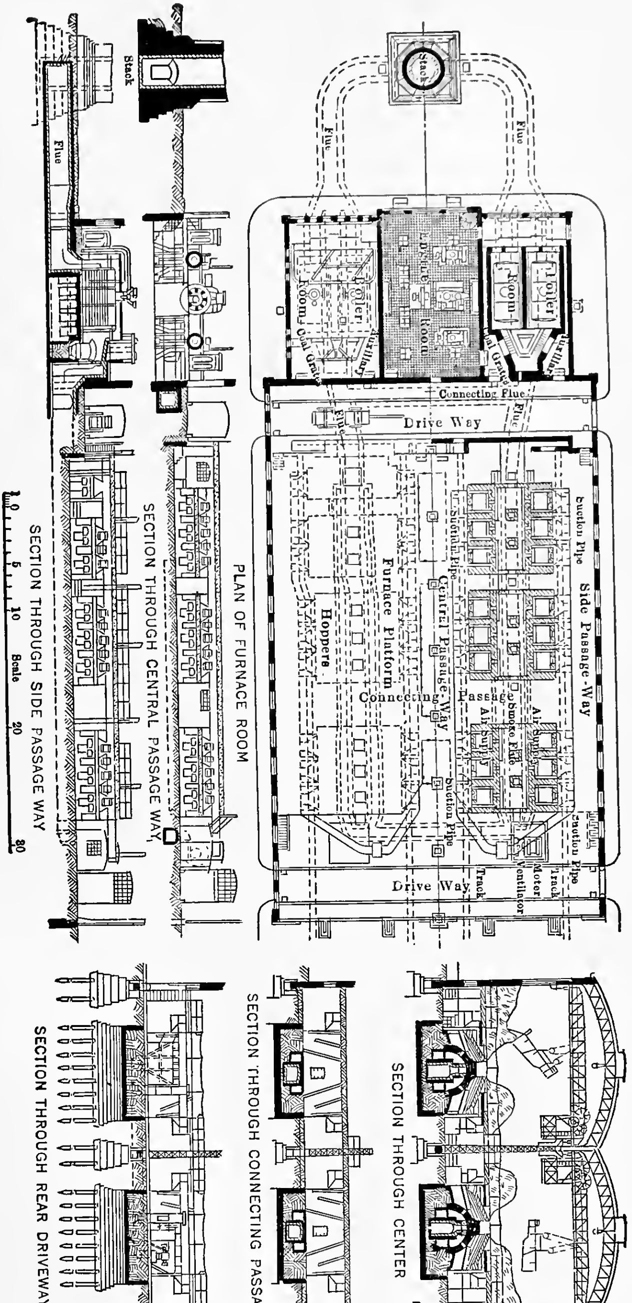


FIG. 110.—Municipal Incinerator for Refuse, at Bullerdeich, in Hamburg, Germany. (F. Andreas Meyer.)

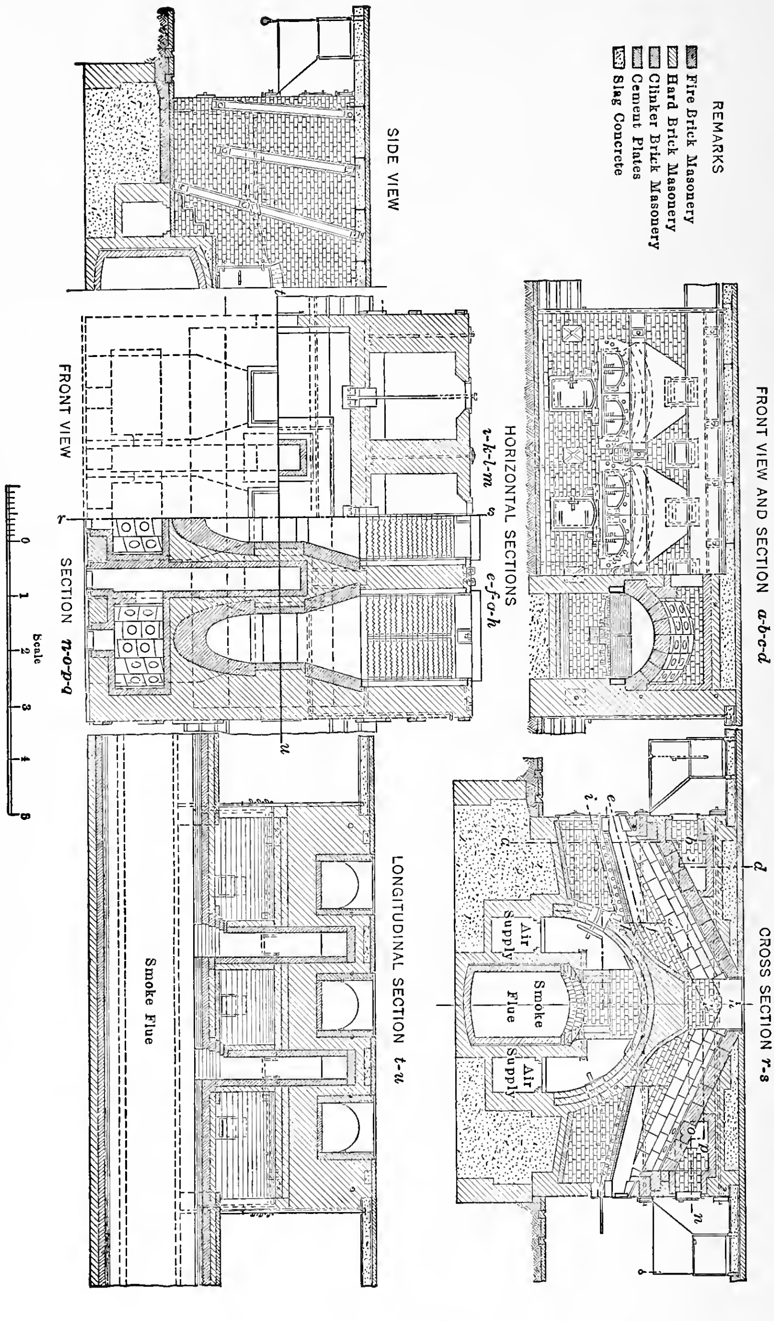


FIG. 111.—Municipal Incinerator for Refuse, at Bullerdeich, in Hamburg, Germany (F. Andreas Meyer.)

ficient manurial and calorific values. Experience in Paris, however, proved, as elsewhere, that the manurial value is small and that it is difficult to obtain a market for it except on very sandy and barren soil. It was decided, therefore, to repeat a trial for incineration.

In February, 1909, and under favorable conditions, another test was made at Vitry by the Association Parisienne de Propriétaires des Appareils à Vapeur. About 12,000 lb. of refuse were burned in seven hours and fifty minutes. The temperature maintained was 1560° Fahr., and 1.8 lb. of steam were produced from 1 lb. of refuse. It was hoped that a conversion into electrical energy would not only supply the demand of the works, but make available a surplus for disposal to the municipality.

Since then two plants of the Heenan type have been built, at St. Ouen and at Issy. The St. Ouen plant has four 6-cell units, each having a capacity of 120 tons per twenty-four hours, with trough grates, electrically operated top-charging and operating doors controlled from the clinkering floor. The clinker is withdrawn by a winch into a special skip, which is picked up by a traveling crane and taken to a clinker-cooling apparatus, where the clinker is broken up and immersed in water. The clinker is generally used for brick making.

A test of four days and five hours showed that about 1 ton per cell could be incinerated in one hour. The residuals after burning were 18% of the refuse delivered. The electrical energy produced was 856 kw. per hour. The evaporation per pound of refuse was 0.93 lb. of water. Several collecting trucks were supplied with storage batteries charged at the works.

Meldrum plants were built in the suburbs of Ivry, Romainville, and Gennevillières, of similar capacity and efficiency.

Although the Paris incinerators have destroyed the objectionable quality of the refuse, the anticipated steam production has not been generally realized.

22. Other Incinerating Plants.—In addition to the plants just described, there are many in use for burning mixed refuse at high temperatures, particularly in England, where, in almost all cities, such refuse contains a large proportion of unburnt coal. Descriptions of many are available in the engineering press and in the publications of Maxwell, Goodrich, Parsons, Morse, and others. Brief descriptions of essential parts of several American and European high-temperature plants will be found also in this chapter under C. Design and Construction, and D. Tests.

The success of an incinerating plant should be judged by the degree to which it complies with the laws of combustion, the available heat

units produced, and the economy of operation. Yet, some of the best of such plants in the United States, as at San Francisco, Berkeley, and Seattle, have been ordered suspended, because it was found to be cheaper to dump the refuse at sea or to fill up low land without objection.

G. ADVANTAGES AND DISADVANTAGES

There are a number of advantages and disadvantages in refuse disposal by incineration, other than cost. Their relative importance will vary in different localities, and must be considered carefully in each case. The most important are given below.

Advantages

a. Incineration permits of the single-can house treatment, with the so-called mixed collection. It takes a slight burden off the householder in keeping the different parts carefully separated, and permits of an easy and generally clean collection.

b. The cost of collection can be reduced, because good incinerators can be built in interior parts of a city. They can frequently be established near the centers of the largest production of refuse, thus reducing the length of haul considerably.

c. The possibility of having several plants in a city reduces the risk of interrupting the disposal in case of the destruction of one of them by fire or otherwise.

d. The process is thoroughly sanitary, and destroys all organic matter and germ life.

e. A revenue is available from the products of incineration, namely, from steam and clinker, and it is possible that some revenue could be secured by the sale of dust and fine ashes as a fertilizer.

Disadvantages

a. The dust produced within the incinerator building during operation. This, however, is not a disadvantage to the general public.

b. The chance of the escape of unconsumed offensive fumes from the chimney top. This is particularly to be feared when the charged refuse is deficient in combustible matter, and in low-temperature furnaces, which, however, can be substantially obviated by proper operation.

c. With a mixed collection, the necessity of hauling all kinds of

refuse to the incinerators, instead of hauling some parts, as ashes, to a near-by dump, increases the labor of collection.

H. EXAMPLE OF COMPUTING THE CALORIFIC VALUE OF THE VARIOUS CLASSES OF REFUSE

According to Dawson, the calorific value of various constituents of ashpit refuse, when dry, in terms of heat units developed per pound of combustible, is as follows:

Coal	14,000 B.t.u.
Coke	12,000 B.t.u.
Bones and offal	8,000 B.t.u.
Breeze and cinders	6,000 B.t.u.
Rags	5,000 B.t.u.
Paper, straw, fibrous material, and vegetable refuse	3,800 B.t.u.

Assuming that these classes of materials in other places have the same calorific values, it is a simple matter to compute the approximate burning qualities of the refuse of any city when we know the relative proportions of the various classes.

In England it is found in practice that from 1 to 2 lb. of water can be evaporated per pound of refuse. In some German cities it was found that from ½ to 1 lb. of water could be evaporated per pound of refuse. Let us now take, for example, the refuse of New York, and compute the heating power from the constituents of the various classes of wastes. We have, then:

1. The ashes contain 25% of unconsumed coal, having a calorific value when dry of, say, 10,000 B.t.u. The remaining 75% is inert matter.

2. The garbage when dried contains about 23% of animal and vegetable matter, with a calorific value of, say, 8000 B.t.u.; 5% rubbish and combustible waste having a calorific value of, say, 4500 B.t.u. The remaining matter contains about 2% of inert matter and 70% of water.

3. The rubbish contains about 95% of combustible matter, having a calorific value of, say, 4500 B.t.u. The remaining portion is inert matter.

4. The street sweepings contain about 25% of organic or combustible matter, having a calorific value of, say, 4000 B.t.u., about 40% moisture, and about 35% inert matter.

Taking, then, 100 lb. of total city waste and resolving it into various percentages, we obtain in tabular form the following results:

	Pounds of each class of wastes	Water		Combustible Matter		Inert Matter		Calorific Value of Combustible Matter	
		Per-centage	Pounds	Per-centage	Pounds	Per-centage	Pounds	B.t.u. per Pound of waste	Total B.t.u. in wastes
Ashes.....	66	.....	.....	25	16.5	75	49.5	10,000	165,000
Garbage...	10	70	7.0	28	2.8	2	0.2	7,500	21,000
Refuse.....	6	.....	.....	95	5.7	5	0.3	4,500	25,600
Sweepings..	18	40	7.2	25	4.5	35	6.3	4,000	18,000
Totals....	100	.....	14.2	......	29.5	......	56.3	......	229,600
Averages..	......	.....	.....	......	......	......	......	5,810	......

Thus we have a total of 229,600 B.t.u., corresponding to about 16½ lb. of coal, having a calorific value of 14,000 B.t.u., and 14.2 lb. of water. This water must first be evaporated, and the residual value of the combustible may then be considered available for producing steam.

Assuming 7 lb. of water evaporated per pound of coal, it will require 2 lb. of coal to evaporate the 14.2 lb. of water in the refuse, and the difference between 2 and 16½, or 14½ lb. of coal is the coal equivalent of the 100 lb. of mixed refuse. On the basis of 7 lb. of water evaporated per pound of coal (a modest estimate for steam at 100 lb. pressure from any good boiler under ordinary working conditions), we have 7 times 14½, or 101 lb. of steam per 100 lb. of mixed refuse, equivalent to 1.01 lb. of steam per pound of refuse burned. This is the quantity of steam which New York refuse, properly incinerated in a destructor of modern type, should develop. This figure also compares favorably with results obtained in England under ordinary daily conditions.

I. SPECIFICATIONS FOR CONSTRUCTION

Specifications for refuse incinerators are generally accompanied by one or two general lay-out and location plans, and are prepared so that different manufacturers can base their bids on their own patterns and designs. On this account, each bidder should be required to guarantee the operation of his design, both for efficiency and economy.

The form and arrangement of the specifications for refuse incinerators need not differ from those required for other municipal works. The specifications for materials and methods of construction and for machinery are not essentially different.

Preceding the specifications, of course, there should be complete instructions and information for bidders. The first section of the specifications should contain concise definitions of all terms in regard to which there might be misunderstanding.

The requirements may then be stated, about as follows:

1. A brief statement of the work to be done.

2. A description of the location of the plant, the size, elevation, and grades of the lots, and the subsoil on which it is to be built.

3. The capacity of the plant, in tons per twenty-four hours.

4. The sanitary requirements in the operation of the plant: Cleanliness, freedom from dust, smell, smoke, etc.

5. Maximum and minimum temperatures in combustion chamber. Average temperature and rate of combustion.

6. Statement of composition of refuse: Percentages of moisture and combustible matter.

7. Arrangement of furnaces, combustion chambers, pre-heaters, forced-draft apparatus, air ducts, flues, and steam boilers in units. Each unit to consist of one furnace having four grates, four drying hearths, four clinker-cooling chambers, one combustion chamber, one forced-draft apparatus with air-heater and air-valves, one steam boiler of the water-tube type, with the necessary flues, firing tools, and recording instruments.

8. Statement of the number and capacity of units. Provision in design for additional units.

9. Conveying system for handling refuse and clinker; ventilating system; feed-water pumps; fuel-oil system; electric equipment for light and power; system of pipes and appurtenances for conveying steam, water, and oil; crushing plant for crushing and screening clinker; baling press for compacting and baling tins; instruments for recording and controlling operation of plant; tools and supplies for making repairs, etc.

10. Size or capacity of conveying, ventilating, steam, and water-pipe systems, boiler feed pumps, electrical equipment, crushing plant, baling apparatus, etc., with provision for adding to the equipment without undue expense.

11. General description of plant; refuse, how delivered; refuse weighed; platform scales; loads, how emptied; containers or conveying apparatus; storage of containers; refuse transported or handled mechanically; appliances constructed so that no refuse will

be spilled, and so that they can be readily cleaned. No stationary bins, hoppers, or floor space for storage of refuse. Provision for removal of cans or other incombustible material too large to be put in furnaces. Refuse to be fed at top of furnaces; provision for proper stoking. Furnaces to have apparatus for burning oil when required. Heat of clinker and ash returned to furnace. Clinker and ash removed below floor level, and conveyed to crusher. Provision for crushing and screening all residue from furnaces, and baling tins and scrap. Gases from furnaces to pass through boilers for generating steam, and through heaters for pre-heating air for combustion, and then to the stack. Air for combustion taken from near top of building, conveyed by blowing apparatus through pre-heaters and distributed to furnaces. Steam which is not used for operating the incinerator to be conducted to adjoining room or building where electric generating plant is erected. Surplus steam, how disposed of.

12. Incinerating plants to comprise all weighing scales, hoppers, storage containers, conveying equipment, feeding apparatus, furnaces, fuel-oil equipment, boilers and feed pumps with appurtenances and connections, pre-heaters, flues, blowers, air compressor, crushing and screening apparatus, baling press and appurtenances, electrical equipment, pipes, valves, and fittings, instruments, tools, supplies, etc.

13. Contractor to present bid for entire work of building the incinerating plant, beginning with weighing scales and ending with conveyors for clinker and ash, and including foundations, flues, buildings, chimney, furnaces, boilers, generators, etc., etc.

14. If it is intended to use the excess steam for power, and the clinker and ash for road making, concrete, etc., this should be stated, and also that the residue must be completely incinerated.

15. Contractor to present full plans and descriptions of entire work. The plans and descriptions to comply with requirements of the specifications. Drawings to be in complete detail, and show the incinerating building, with provision for its extension to include additional units, the chimney, the crushing plant, and the electrical equipment, etc. The plans to be in enough detail to indicate the character and dimensions of all foundations, flues, the chimney, etc.; also the weights per square foot on the various foundations, size and location of doors and windows, etc., etc.

16. The size of the drawings may be specified and also such particulars as scales, titles, dimensions and dimension lines, etc.

17. City's engineer to examine drawings, and, when approved, they become a part of the contract; but, engineer's approval to refer only to general design, and not to relieve contractor of responsibility

for correct proportioning of any parts of the work or for any defects in construction.

18. Contractor may be allowed to furnish or erect a certain structure or apparatus differing from that originally specified, but shall first submit drawings and descriptions which must be approved by the engineer.

19. Statement in full of scope of proposal: Location of plant and its capacity, complete list of all parts of the plant, and provision for detailed test after completion.

20. The price bid to be a lump sum for the construction of the buildings and chimney, the furnishing and erecting of all machinery in complete working order, and the conducting of a test in accordance with program specified by the engineer.

21. A provision may be inserted requiring the bidder to guarantee a certain cost per ton as the net cost for incinerating refuse containing certain percentages of water and combustible (for instance, for San Francisco, these quantities were 1000 lb. of water and 460 lb. of combustible per ton). Then it may be specified that he be required to guarantee also decreased or increased costs per ton below or above the first guaranteed cost for decreased or increased quantities of water or increased or decreased quantities of combustible in the refuse.

22. A provision may also be inserted requiring the bidder to guarantee the number of pounds of refuse (of specified composition) which will be incinerated per square foot of grate area per hour.

23. The bidder to be required to state the probable gross rate of evaporation in the boilers, from and at 212° Fahr., per pound of refuse (of specified composition) consumed.

The following method of determining the lowest bid was adopted in San Francisco:

The bids were compared on the basis of the lowest net annual cost for operation. This bid was made up of 10% of the bid price for construction added to the labor cost for the year, the latter being determined by multiplying the guaranteed cost for labor by the total number of tons per year, computed from the guaranteed capacity of the plant. From this sum was deducted the annual value of the steam generated, computed from the guaranteed rate of evaporation, an assumed value of steam, the total annual tonnage, and also the value of the clinker.

The lowest price thus ascertained was designated as the lowest bid.

The specifications may give detailed descriptions of all parts of the incinerating plant, machinery, materials, tools, workmanship, etc., under headings somewhat as follows:

Handling refuse; furnaces; fuel-oil equipment, air and ventilation;

furnace gases; handling clinker; steam generation; pipes, valves, and fittings; electric light and power equipment; instruments; tools and supplies; and materials and workmanship.

There should be a statement as to the contractor's guaranties relating to nuisance, smoke, gases, dust, temperatures, residual clinker, shut-downs, rate of incineration, and costs per ton. He should also be required to guarantee the stability of the foundations, buildings, and chimney, and also the construction and workmanship on all parts of the machinery.

The details of the tests should be specified, and should define the time when they are to be made, their number, and length; also details of any special tests which may be required (for instance, with additional fuel, or for evaporation). The expense of making the tests is generally borne by the contractor, but this should be stated.

The methods of ascertaining the costs of incineration during the tests should be fully stated, in order to avoid any misunderstandings or disputes as to the final results.

Then should follow the usual sections relating to "Bonus and Damages," "Acceptance and Rejection," "Time of Completion," "Payments," and "General Provisions."

The sections in specifications which require special consideration, because they are somewhat unusual, are those relating to fire-brick, instruments, guaranties, and tests. There has been a marked similarity in specifications covering these matters.

For fire-brick the San Francisco specifications give the following clauses:

"*Fire-brick.*—All fire-brick used shall be equal to the best grades of the following manufacturers:

"Harbeson-Walker Refractories Co., Pittsburg.
Timmis and Co., Stourbridge, England.
Tornley Iron Co., Leeds, England.
Glenboig Union Fire-clay Co., Glenboig, Scotland.
Hoganus, Stockholm, Sweden.

"*Laying Fire-brick.*—All fire-brick shall be laid with the closest possible joints, with a paste made of the same material of which the fire-bricks are made. The proportions shall be twenty (20) per cent. pulverized fire-brick and eighty (80) per cent. fire-clay, with not more than one and one-quarter ($1\frac{1}{4}$) per cent. of hydrated lime. The fire-clay shall be slaked or wetted at least three (3) days before it is used, and shall be used as a thin paste and not as a mortar."

Toronto, Canada, issued specifications in January, 1915, for a 180-ton refuse incinerator. The specifications for fire-brick are similar to those of San Francisco. They include the Elk Fire-brick Co. and the Gartcraig Fire-clay Co. in the list of manufacturers.

The authors believe that bidders should be given more information about the uses for the fire-brick, and the particular qualities required to meet these uses.

Instruments for reading temperatures, analyzing flue gases, and measuring draft pressures and velocities are not essential to the operation of an incinerator, but, as they promote efficiency, they are frequently included in the plant. The most complete specifications for instruments are in the San Francisco set. The requirements are substantially as follows:

"Sec. 180.—For the Islais Creek Station the contractor shall furnish the following instruments:

"Two (2) Recording Electric Pyrometer Outfits complete with roll charts to read to about 2500° Fahrenheit.

"Three (3) four-foot Platinum Platinum-rhodium Thermo-couple Outfits complete, with quartz or porcelain protecting tubes, and one (1) extra couple and tube for renewal.

"One (1) Indicating Pyrometer with one scale reading to about 2400° Fahrenheit and calibrated for the platinum platinum-rhodium couples, and one scale reading to about 1200° Fahrenheit and calibrated for the medium temperature thermo-couples.

"Ten (10) Double Knife-blade Switches with leads from a suitably located switchboard to fire-end sockets located as directed by the City Engineer. Leads to the platinum platinum-rhodium couples shall be arranged to connect with both recording and indicating instruments.

"Six (6) Four-foot Medium Temperature Thermo-couple Outfits for temperatures up to about 1800° Fahrenheit complete, with one (1) extra fire-end for renewal.

"Two (2) Ellison Differential Draft Gauges.

"Ten (10) U-tube Draft Gauges to read to 10 in. pressure.

"One (1) Simmance-Abady CO_2 Recorder, or equivalent, approved by the City Engineer, with connection to the gas exit flue of each unit.

"One (1) Crosby or Bristol Recording Steam Gauge.

"One (1) Suitable meter, approved by the City Engineer, for continuous measurement of feed-water supplied to the boilers.

"Sec. 181.—The contractor shall provide the following portable instruments for general use at either of the plants as may be desired.

"One (1) Ferry Radiation Pyrometer Outfit complete, including pyrometer with adjustable diaphragm, galvanometer with two (2) direct reading Fahrenheit scales and certificate, telescopic tripod stand, thirty-three (33) feet of leads and traveling box.

"Six (6) Fire-clay tubes four (4) feet long for the above.

"One (1) Flue Gas Thermometer graduated to 1000° Fahrenheit, angle pattern, with Carrying Case; Nos. 2680 and 2685 Hohmann & Maurer's catalog, Book 50.

"One (1) Separable Socket Thermometer for superheated steam, graduated to about 600° Fahrenheit; No. 4927 Eimer & Amend's catalog, page 357.

"One (1) 18″ Thermometer, graduated 30° to 212° Fahrenheit in 1–10 degrees, with certificate and case; No. R 5809A Braun-Knecht-Heimann's catalog, page 387.

"One (1) Pitometer suitable for measuring the velocity of gases in the flues.

"One (1) or more Self-recording Steam Meters, of capacities suitable for measuring all the steam used while testing the incinerating plants, as required and directed by the City Engineer.

"One (1) Calorimeter suitable for measuring the quality of steam entering the superheater, complete.

"One (1) Set of apparatus for flue gas analysis consisting of the following items or equivalent. The numbers refer to Eimer & Amend's catalog of 1907."

* * * * * *

This list is far more complete than is generally required. The Toronto specifications call for a continuous recording radiation pyrometer, a CO_2 recorder, thermometers for recording the temperatures of chimney gases, pre-heated air, and outside air, and draft-gages for recording pressures in the ashpits, flues, and chimney. This is the usual equipment called for. The plans and specifications should provide for a suitable dust-proof room in which to keep the recording apparatus. Cranes and other machinery exposed to dust should also be properly protected.

A most important part of incinerator specifications relates to the guaranties and tests. The requirements of guaranties are based on the conception that an incinerator, like a pumping engine or boiler, must operate at a guaranteed efficiency, and must come up to certain standards set forth in statements by the bidder. Plans and specifications are drawn to allow each bidder or manufacturer to make use of his own patterns for castings, etc., and also, to a limited extent, of his own general design and method of operation. On this account, bidding should not be limited to labor and materials, but should also partly include design. The contractor guarantees his design to produce certain results. The guaranties include, not only the results of the operation of the furnaces, boilers, and appurtenances, but also the labor and power required to produce the results in practice.

The value of an incinerator to a purchaser is taken to be the net cost of operation, which includes credits for the products of operation and debits for the labor and other elements of cost. Bids, therefore, have been compared on this final net annual cost rather than on the first cost. A more expensive, but more efficient, plant, with lower annual cost, may secure the award. This method of guaranty was first used at Milwaukee in 1908. The bid of the Power Specialty Company was not the lowest one received for construction, but it

secured the work on account of the better over-all efficiency guaranteed. In addition to the guaranties on efficiency and cost, certain others, fixing sanitary standards of operation, should be included.

The Toronto specifications required substantially the following guaranties:

"(1) That there will be no smoke at any time escaping from the chimney of a degree of darkness or density greater than that determined by Chart No. 1 of Ringlemann's smoke scale, as supplied by the United States Geological Survey.

"(2) That there will be no dust emitted from the top of the chimney.

"(3) That the residue shall not contain more than one per cent. of organic matter, exclusive of carbon."

A determination of the capabilities of the plant to fulfill such guaranties must be based on tests. The method of conducting these tests must be described clearly in the specifications, as a safeguard to the purchaser and in fairness to the contractor. The character of the refuse to be used during the tests must be defined as closely as practicable, so that the contractor has a reasonably definite basis for his guaranties. (See Chapter X. D.)

During the past few years there has been an improvement in the sections of specifications covering the character of the refuse. This matter is covered in the Toronto specifications as follows:

"The contractor hereby guarantees that the following conditions will be fulfilled, subject to the judgment of the engineer, when the furnaces are incinerating, without additional fuel, at or about their rated capacities, refuse containing not more than nine hundred and forty (940) pounds of water per ton, determined by evaporation tests, and not less than four hundred and sixty (460) pounds of combustible per ton, determined by combustion tests."

Specifications for garbage furnaces are more often prepared by contractors and manufacturers than by municipal engineers, and are offered to the purchaser as a description of the plant they propose to build and the character of the workmanship and materials they propose to furnish. This usage is frequently found in small cities.

Usually, however, better results are to be expected if thorough and complete specifications are prepared by the city through its engineers. Under such specifications, and with proper inspection during construction, a plant with a longer useful life will generally be secured, and better results in operation will follow, if, for instance, leaks of cold air, due to poor construction, are eliminated. Also, a low cost for repairs will follow execution under good specifications.

J. SUMMARY AND CONCLUSIONS

Burning refuse systematically has been practiced for many years in America and abroad. American practice started with the burning of garbage alone, using coal as a necessary auxiliary fuel; European practice has been developed along the lines of an incineration of mixed refuse without an additional fuel. Furnaces of special designs have been built for each of these practices. Within the past few years in America several large mixed-refuse incinerators have also been operated quite successfully. Each method of burning can be sanitary and efficient through proper design and operation; their relative preference for a special case will usually depend on the annual cost, including fixed charges.

The principles of refuse incineration are now well established, and their practical application is becoming better understood; yet there is still a need for a more general use of the best designs and more intelligent operation, and the preparation of specifications to insure proper construction and operation.

The following conditions may be considered among the essentials of a satisfactory incinerator:

The design must be arranged so that the charging with refuse can be rapid and thorough, and permits but a minimum of cold air to enter the furnace during a charge. The refuse for every charge must be well mixed and contain a sufficient quantity of combustible matter.

The cells and flues should be arranged so that only pre-heated air passes over every part of the fire, and that the subsequent fumes enter a sufficiently large combustion chamber, adjoining the cells, on their way to the boilers and chimney.

The temperature of the developed heat must be high enough at its minimum to destroy effectually all organic solid and gaseous matter before reaching the chimney, which requirement, therefore, almost invariably necessitates the use of forced draft and a combustion chamber, and in low-temperature furnaces frequently the addition of some fuel.

No dust should escape from the chimney, which requirement demands a properly designed dust settling chamber, to give a sufficiently slow velocity to the ascending gases.

Boilers for steam production should be placed immediately beyond the combustion chamber, in order to get the greatest available heat. Pre-heated air for the grate fires should be produced beyond the boilers.

Ashes and clinkers should be removed quickly and inoffensively, with a minimum of dust; and be utilized, as far as possible, by their conversion into salable materials, unless filling up land is more desirable.

In Europe steam production from mixed refuse, and its utilization,

is practically everywhere accomplished, notwithstanding that the percentage of unburnt coal contained in domestic refuse is no greater, but generally less, than in America, except where oil and gas are the principal fuels. (See Chapter I. G.) Steam is utilized, not only to move cranes, buckets, valves, and doors, but to generate electricity for both lighting and power purposes. Westmount, Que., has utilized the steam produced by incineration in this manner for many years. We have but a few such cases in the United States, yet the conditions inviting the same results exist here as well as they do in England. We should therefore give more attention than heretofore to the utilization of steam, chiefly to reduce cost rather than to expect profit.

The reasons why American incinerators rarely develop much steam, are, first, the more common practice of erecting plants of cheaper first cost, which are not designed for efficient steam production, and secondly, unskillful operation, which produces low temperatures and consequently incomplete combustion with bad odors.

The adoption of low-temperature furnaces, when the average material has a sufficiently high combustible value, is justified only in the case of perfect reliance on an efficient operation, both in the collection service and burning of the garbage. Most of our present furnaces frequently do not produce a sufficiently high temperature to prevent the occasional escape of offensive odors, because of neglect partly in failing to add enough fuel when required to destroy all the odorous gases which are to be expected and partly in failing to mix the materials of the charges so that they can produce a sufficiently high temperature to destroy all the objectionable organic matter.

The details relating to the operation of refuse incinerators have lately developed markedly along the lines of greater mechanical control, eliminating hard labor, speeding up the various operations, increasing the efficiency, and improving the combustion.

If refuse can be incinerated in properly designed and operated high-temperature furnaces, without producing a nuisance, which has been amply demonstrated in practice for years both abroad and here, it is feasible then, not only to burn the refuse at selected points within a city, as in London, and thus greatly shorten the collection haul and reduce its expense, but also to simplify the house treatment in many districts where separation is now irksome. The utilization of hard clinkers as a concrete aggregate in building operations would reduce the cost of their removal to a distance, and the generation of electricity would reduce the total cost of incineration, and sometimes also of the collection.

In any particular case sanitary results coupled with careful estimates of cost should decide whether or not incineration is best.

CHAPTER XI

REDUCTION OF GARBAGE

The development of the reduction method for the final disposal of garbage has been due, in a great measure, to American initiative, for, with the exception of a few experimental operations, no plants have been built in other countries. Without doubt, the greater wastefulness of the American people is one reason for this development, as it produces a garbage rich in recoverable elements.

The reduction method is a combination of mechanical and chemical processes whereby the garbage is separated into four parts: Volatile matter (driven off as gas), water, grease, and " tankage." The latter is a dry material, which is somewhat stable, mostly fibrous, and of vegetable and animal origin. The grease and tankage have market values, which is the chief reason for the development of this process. Garbage grease is used in the manufacture of soap, candles, glycerine, and other materials, and has been selling at from 3 to 10 cents per pound. The tankage is used as a filler or base for certain fertilizers, and has been selling at from $5 to $10 per ton, generally according to its ammonia content. The volatile matter driven off contains foul-smelling gases, and this source of odor must be destroyed by fire or otherwise, if nuisances are to be avoided.

The commercial character of the process, the risks involved, and the need for expensive machinery and skillful operation, have generally prevented the process from being adopted in cities with populations of less than about 75,000. As it can be used for the disposal only of garbage and dead animals, it therefore requires a separate collection system.

The reduction of garbage into grease and fertilizer originated in Austria, where, in Vienna, the " Merz " process was first introduced experimentally, but was not developed successfully on a working scale for large cities until its introduction into America at Buffalo, in May, 1886, by Mr. H. A. Fleischman, who organized a company to " manufacture grease and fertilizer from city refuse." A contract was made with that city whereby the garbage was to be kept separate from all the other refuse and delivered at the company's works.

The topography of American cities and the distribution of the population over comparatively large areas, have provided opportunities for the ready disposal of ashes, rubbish, street sweepings, and other more or less inert kinds of refuse, by dumping on low lands. As garbage, when dumped in this way, decomposes and produces odors and nuisances, a different method for its disposal was demanded. Conditions in America were favorable to the development of garbage reduction, chiefly on account of the high percentage of grease obtainable. As an inoffensive burning of garbage, unmixed with other kinds of refuse, was found to be expensive, the possibility of obtaining a revenue by using the reduction process for its disposal became attractive, and the Austrian invention was received favorably by American promoters. Several processes were developed subsequently and became known by the names of their respective inventors. These are described briefly herein.

A. FUNDAMENTAL CONSIDERATIONS

Reduction processes consist of a breaking up of the garbage by the application of heat and mechanical agitation, so that the valuable constituents can be recovered and prepared for the market. Osborn has classified these processes as follows:

" At the present time garbage is usually reduced by one of two methods, and, for distinction, all the plants operating can be considered as using either the drying or the cooking method.

" The two methods might be described as follows:

" 1. *Drying Method.*—The drying method consists in crushing or grinding the crude garbage and passing it through direct-heat driers to drive off the moisture and break down the cells. The dry solids are then placed in extractor tanks and the grease is recovered by percolation, using gasoline as a solvent.

" 2. *Cooking Method.*—The cooking method consists in placing the garbage in digester tanks, where it is cooked, and then extracting the free grease and moisture by pressing. The solids from the presses are then dried, and, in the modern plants, the dried tankage is percolated to recover the grease that is not extracted by the presses.

" The relative advantages of the two methods give rise to a difference of opinion, although at the present time the majority of plants are operated by the cooking method. The advantages and disadvantages of the two methods might be summed up as follows:

" *Advantages of Drying Method:*

" 1. The first cost of the plant is less, due to the smaller equipment and building space required.

" 2. The operating costs are less, due to the smaller amount of labor and power required.

" *Disadvantages of Drying Method:*

" 1. Carbonizing of the grease in the drier, due to the high temperature required, so that the maximum amount of grease is not recovered.

" 2. The material is not broken down to let the solvent act as readily on the grease particles and allow maximum recovery.

" 3. The mechanical condition of the by-products is not desirable without additional treatment.

" 4. There is a greater volume of gases to be deodorized, making it difficult to deodorize it economically.

" *Advantages of Cooking Method:*

" 1. The cells of the material are more completely broken down, so that a larger amount of grease can be readily recovered.

" 2. All material is enclosed during the process, so that the gases are more readily deodorized and their volume is less.

" 3. In the modern plants, the mechanical condition of the by-products is better.

" *Disadvantages of Cooking Method:*

" 1 Increased first cost of building and equipment.

" 2. Increased operating cost.

" 3. Increased maintenance cost.

" The by-products from either method have the same relative market value. In plants that have been operated by both methods the experience has been that the additional amount of grease recovered by the cooking method has more than offset the increased cost, and at the same time the odors were eliminated to a larger extent."

The desired results from reduction processes are the production of the greatest quantities of grease and tankage, having the most valuable qualities, in the most economical way, and with as much cleanliness and freedom from nuisance as practicable. The raw material is garbage, which generally contains more than 70% of water and less than 30% of solid matter. The water is useless. The solid matter contains a mixture of vegetable and animal fats, and of nitrogen, phosphate, and other elements which are valuable as fertilizers.

The garbage reduction process differs from that used in the manufacture of other oils and fats chiefly in the facts that there is a comparatively large percentage of water in the raw material, and that both animal and vegetable fats are present. By simply crushing the garbage and allowing sedimentation, some grease can be skimmed off, and the solids have some fertilizing or food value. If the garbage is cooked in an open kettle, grease can also be skimmed off, the water drained away, and solids with some fertilizing or food value can be recovered. The later processes have introduced a greater production of grease by crushing and cooking, and extracting it more completely with solvents. The solids must then be dried to produce a marketable tankage. The escaping waste liquids and gases are

objectionable, and must be treated in a sanitary way. The modern processes have been designed to secure these results with a satisfactory control of the foul gases and liquids.

The design of reduction works requires a special knowledge of the materials to be handled and produced. The most pertinent features will be described.

B. PLANT LOCATION

The fact that offensive gases and odors arise from the reduction treatment of garbage makes it necessary for a city to destroy them completely or, if this cannot be done economically, to remove the works to a favorable or distant locality where odors, if detected only occasionally, would not be objectionable.

The preference should be decided by the community, as to how far it will take a risk. The expense of the works must be increased in order to provide sufficient means both to destroy the offensive gases completely and to occupy land near the city; but a shortening of haul sometimes greatly reduces the expense of delivery. On the other hand, if sufficiently far from residences, and where, as in the neighborhood of similar establishments, an occasional odor may be permissible, the works may be operated less expensively.

The cost due to a longer delivery route is generally much greater. In Milwaukee it was found to be more expensive to establish a reduction plant at the nearest permissible point, on account of the greater cost of delivery, than to build incinerators near the center of the city. In Toronto, where the most economical solution was a reduction plant several miles from the city, but in a neighborhood that was desirable for good residences, it was decided to build an incineration plant, at a less distant point, but in a neighborhood where it was not deemed objectionable. Where a plant cannot be placed at a near point, and it becomes necessary to have a transfer station, with a final delivery by motor truck, rail, or water, the cost of transportation per mile thereby becoming less, it may sometimes be better to select at once a sufficiently distant point, so that it may become permanently established as such in its neighborhood.

In very large cities it has been found more economical and quite satisfactory, as in London, England, to establish a number of incinerating plants within the metropolis, and thereby shorten the length of collection hauls. Such a solution has not yet been attempted with reduction plants, probably for two reasons. One is, that assuming 100 tons of garbage could be disposed of at the same cost, either by a single reduction or a single incineration plant, then it would cost more to establish and operate two reduction plants each of 50 tons capacity,

than two incineration plants each of 50 tons capacity, because the former have more complicated machinery and are more difficult to operate. Another reason is that the odors in the former are more difficult to control because, at reduction works, the odors are produced by the process, while at an incinerator they are prevented or destroyed by the process.

On the other hand, the reduction plants, for instance, at Rochester, Toledo, Chicago, and Los Angeles are quite favorably located as regards haul of garbage and operation of the works. These plants have been in use a number of years, and there has been no apparent disposition on the part of the cities to change their locations. The plants at Toledo and Chicago are in locations adjoining stock yards and packing houses, where odors are expected. The plant location at Rochester, apparently satisfactory, is near the center of the city and in what would usually seem to be a rather critical location.

It thus appears necessary, when considering plant locations, to canvass carefully the local conditions, so that favorable local circumstances may be advantageously utilized.

C. PROCESSES

1. Merz.—In the Merz process the garbage is first dumped into a large hopper and the free water allowed to drain off. It is then spread out, so that foreign matter, such as cans, bottles, rags, metals, bones, etc., can be picked out. The remaining garbage is then ground in crushers, and the comminuted mass is dumped into hot-air driers, or the crude garbage is dumped directly into them. In the driers the mass is stirred with mechanical mixers and dried for a period of from one to six hours, so that the material is partly broken up and much of the moisture driven off. The dried material is dark brown and greasy. In this condition it is put into extractors, or closed tanks, through which a solvent, such as naphtha or benzine, percolates; this dissolves the grease and thus "extracts" it. The grease is recovered from the solvent by heating in closed receptacles which are arranged so that the naphtha is distilled off and the grease remains. This is then drawn off and barreled for sale. The solids, left over after the grease is extracted, are dried, ground, stored, and sold as tankage.

In some of the earlier Merz plants the drying was done in steam-jacketed driers, which required more time and were more expensive to operate than now. In recent plants the crushed garbage is passed through direct-heat driers, in which it comes into direct contact with the hot air, and is dried more quickly.

The gases produced in these several processes are conveyed to a cooling tower and washed with a fine spray of water to reduce their offensiveness.

Reduction works of the Merz type were built and have been operated at Buffalo, Milwaukee, St. Paul, Paterson, St. Louis, Columbus, and Chicago. The plants at Milwaukee, St. Paul, and Paterson have been abandoned, and the others have been materially modified.

2. Simonin.—In the Simonin process the solvent used for grease extraction is applied directly to the garbage before it is dried. The garbage is first dumped on a concrete floor, and the cans and rubbish are picked out. It is then placed in shallow iron pans, built up in successive layers on trucks. The loaded trucks are run into horizontal cylindrical extracting ovens, 6 ft. in diameter and 18 ft. long. These extractors, or digesters, are closed tightly and filled with naphtha. The contents are then heated and digested as long as twenty-four hours by steam coils fixed in the bottom of the digesters. The garbage water and the naphtha not used for extracting grease are both withdrawn as vapor from the digester to a condenser and then to a settling and separating tank, from which the water is drained to the sewer and the naphtha flows into storage tanks.

The naphtha, with the dissolved grease, is drawn off from the digesters into evaporators, in which the evaporation is continued until most of the free naphtha is driven off to the condensers. A solution of grease is left in the evaporating tank from which it is drawn off into the settling tank, and the naphtha is separated from the grease by distillation. The solids or tankage remaining in the digesters are heated several times by live steam, to drive off the water and any remaining naphtha. The dried tankage is taken out, screened, and is then ready for sale as a dilutant for strong fertilizers. The whole process requires about forty-eight hours. The offensive gases escaping when the digesters are opened have caused considerable complaint.

The first plant of this type was built in Providence, in 1890. The works comprised two steam boilers, six extractors or digesters, two settling tanks, two stills, and a storage house for naphtha. Reduction plants of this type were built also at Cincinnati and New Orleans, but they have been abandoned and replaced by others.

3. Arnold.—The Arnold process was used on a working scale first near Boston in 1895, where a plant was constructed from plans prepared by Mr. Charles Edgerton, of Philadelphia. Therefore, it is sometimes spoken of as the Arnold-Edgerton process. It was the first one to practice the cooking of garbage with live steam. After the glass, tin cans, rubbish, and other undesirable materials are picked

out, the garbage is dumped into vertical digesters, each holding about 8 tons. These have conical bottoms, and are filled at the top from a traveling conveyor. The garbage is then cooked from five to eight hours under pressure with live steam. At the end of this time it has been thoroughly broken up. The mass resembles a thick brown greasy soup, and is withdrawn from the bottom of the digester into receiving tanks from which, at the will of the operator, it is drawn into a power press which separates the liquids from the solids. The liquids consist of grease and water, which are again separated in a settling tank by gravity, and the grease reduced to a commercial form. The water drains off into a sewer, and the grease flows into tanks, from which it is barreled and sold. The solid tankage enters steam-jacketed driers, is agitated, pulverized, dried, ground, screened, and sold as a filler for fertilizers.

In some of the later plants the solid matter coming from the driers is treated a second time with a solvent while passing through supplementary percolators or extractors, and an additional quantity of grease is withdrawn, which also increases the fertilizing value of the tankage. In order to render the steam and gases from the digesters and other apparatus less offensive, they are conveyed to condensers and boilers before they are discharged into the outside air. Plants of this type have been built and operated at Boston, Philadelphia, New York, Baltimore, and Rochester.

4. Holthaus.—In Bridgeport, Conn., in 1887, a method was utilized differing only slightly from that introduced by Simonin. Naphtha was used for extracting the grease in digesters of smaller capacity, and the machinery and apparatus were of better design and construction. The plant was destroyed by an explosion of the naphtha vapors. Another Holthaus plant was built in Syracuse, but, instead of using naphtha, the grease was extracted with steam. This plant was destroyed by fire. New Bedford adopted this sytem in 1894, and built works 3 miles from the City Hall. Naphtha again was used, but only for extracting the grease left in the tankage after most of it had been removed previously by steam. Again an explosion destroyed the plant.

5. Chamberlain.—The " Liquid Separating Process," invented by Mr. M. H. Chamberlain, was first used at Detroit in 1898. It was recommended as an improvement on the previous processes. The Detroit works were built at French's Landing, about 20 miles outside the city. The principal new feature is a special digester, the bottom of which is provided with three concentric circular cylinders having double walls, which are closed at the top and open at the bottom. The sides of the cylinders are perforated. After the cooking period, steam at high

pressure enters the digester so as to force the cylinders up and drive out the liquids carrying the grease. The water and grease which have been pressed out are separated by gravity, and the solid matter is dried and otherwise prepared for the market. Plants of this type were built also at Indianapolis, Cincinnati, and Washington.

6. Wiselogel.—Mr. Frederick G. Wiselogel was for many years connected with the construction of the Simonin and Merz garbage reduction plants and later with the St. Louis Sanitary Company. The reduction plant at Vincennes, Ind., built in 1902, is perhaps the first one which is distinctively of this type. The Wiselogel process is described as follows by the Secretary of a Boston Company organized to promote it:

"Our apparatus consists of a self-contained rendering tank and drier combined. It is a steam-jacketed cylinder of cast iron, 5 ft. internal diameter and 12 or more feet long, provided with a shaft and reel to stir the mass within. The material to be reduced is fed in at the top of the tank, to which an air or vacuum pump is attached, and, being constantly in motion, produces an inward draft while the tank is open, thus preventing any odors from escaping.

"When the tank is filled, the door is closed and clamped. Steam is admitted and the reel is set in motion, the air pump and condenser still being in operation. The water, together with the grease, assembles in the bottom of the machine, and is pumped into the cooling tank, where the grease is drawn off into barrels and is ready for market. The water is led off as a harmless effluent into the sewer. Relieved of the water and grease, the residuum is dried in the same machine, and, during the entire process, by the aid of the vacuum pump, all vapors and gases are drawn from the machine and forced through a condenser and separator where the vapors are condensed and the gases diverted to a specially constructed consumer. When the residuum or tankage is thoroughly dried, it is discharged from the machine as a commercial fertilizer. This whole operation consumes about eight hours' time.

"The material suffers no exposure from the time it is fed in at the top until it is discharged, a dry and odorless product, ready for shipment."

The Vincennes plant was destroyed by fire in 1908 and not rebuilt.

7. Edson.—The Edson Reduction Machinery Company, of Cleveland, had previously developed a process for treating fish waste material in a sanitary manner, and built in Detroit works for garbage treatment in hermetically sealed digesters, driers, and extractors. In 1907, after a year's operation, the works were closed, as they would not fulfill the terms of the contract.

In 1906 the Edson process combined with the Chamberlain process was introduced at Cleveland, and put in practice at the reduction plant at Willow. It was the first plant owned and operated by a city, and the works have been gradually improved.

The garbage is first cooked with steam, under 70 lb. pressure, in

24 digesters, each having a capacity of 10 tons per day, for six to eight hours, and then the grease and water are forced by the steam pressure into settling tanks from which the grease is skimmed off and barreled. The solids from the digesters are conveyed to steam-jacketed driers, fitted with revolving paddles, and then dried for from six to eight hours. The dried material is discharged into percolators, in which the grease is extracted by a naphtha solvent. The remaining solids are dried, screened, crushed, and made up into a marketable tankage. The plant is about 9¾ miles from the City Hall, and is operated successfully. Fig. 112 is a diagram showing the recovery of grease and tankage. The successful development of this first municipal reduction plant

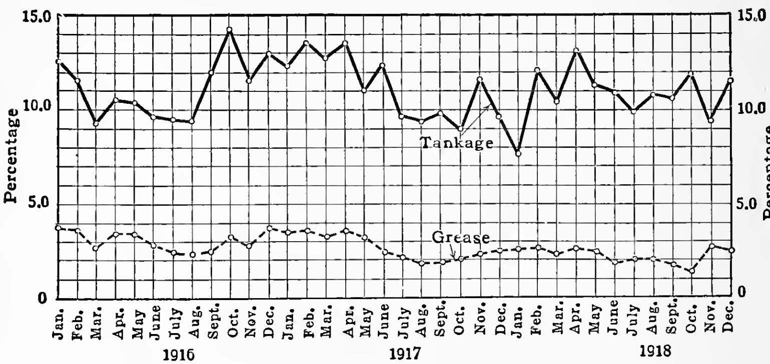


FIG. 112.—Monthly Recovery of Grease and Tankage, Cleveland Reduction Plant.

was due to the efficient and devoted efforts of Mr. W. J. Springborn, President of the Board of Public Service.

Similar processes have been developed also by Flinn, Wheelright, and others. More extended accounts of these processes are given by Morse.*

8. Cobwell.—The most recent development in garbage reduction is known as the "Cobwell" process, invented by Mr. Raymond Wells. It has been adopted at Los Angeles, Rochester, and Staten Island, N. Y., and was used at the Panama Pacific Exposition. The garbage, after being placed in the reducer, a round, flat-bottomed, covered tank having a diameter of at least twice its height, is first flooded with naphtha and then cooked in these air-tight, steam-jacketed tanks, under a pressure of about 85 lb. per square inch. Agitator arms in the tanks keep the material in motion. The temperature of the garbage and gasoline must be maintained at less than 200° Fahr., which causes

*"The Collection and Disposal of Municipal Waste," First Edition.

the water to be carried off with the vaporized gasoline. After the garbage is dry, the temperature in the tank rises, thus indicating when the removal of the moisture is complete. The dried garbage is then washed several times with gasoline, to extract the grease completely. Finally, live steam is injected for a short time into the resulting tankage, which is thereby finally dried. After crushing and screening it is ready for sale. The process, as followed at New York, is described in detail later in this chapter.

9. Chicago's Process.—Garbage reduction in Chicago is based on the use of so-called "direct-indirect" heat driers, and has been developed largely by Col. H. A. Allen. The garbage is first run through

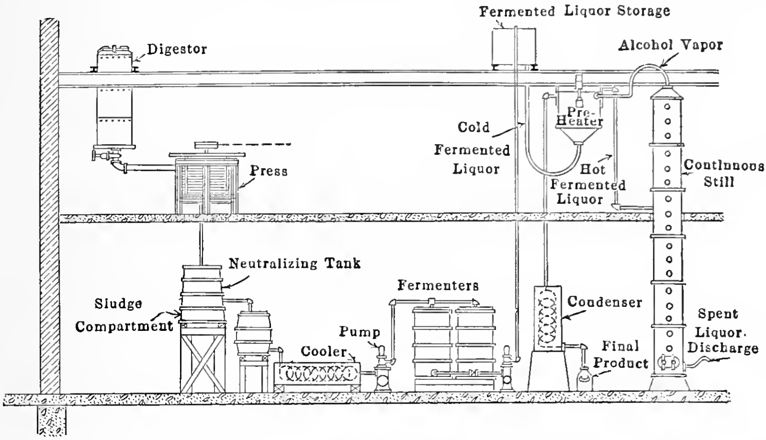


FIG. 113.—Experimental Alcohol Equipment at Garbage Reduction Plant, Columbus, Ohio.

crushers, to break up large material, thus permitting more efficient drying. The crushed material is then fed to driers, which are built with double shells, the inner one being fitted with perforated lugs for stirring the garbage. Hot air passes through the annular space, from which a part escapes into the garbage through the perforations in the lugs. The dried material is then percolated for the recovery of grease, and the tankage is dried, screened, milled, and prepared for the market. Special stacks are provided for cleaning the drier gases.

10. Miscellaneous Processes.—Experiments were made in Columbus (1916–17), on the recovery of alcohol from garbage by a process invented by Dr. J. J. Morgan, of Chicago. The experimental plant is shown in Fig. 113. The garbage is first cooked in a digester, with from 2 to 4% of 60° sulphuric acid under 60 lb. pressure, for about two hours, after which it is partly neutralized and then discharged into

a screw press. The liquor from the press flows to a neutralizing tank, and the solids are dried, percolated for grease recovery, and then converted into tankage. In the neutralizing tank the grease is first separated from the liquor, and the latter is then treated with lime, which forms a precipitate. This settles out and is made into tankage. The neutralized liquid is then cooled and fermented with yeast for from thirty-six to seventy-two hours. Finally, the fermented liquor is heated and distilled for the recovery of alcohol.

From 2000 lb. of selected garbage Dr. Morgan obtained about 50 lb. of alcohol in Chicago and 32 lb. in Columbus. In the latter city it was estimated by him in 1918 that the expense of extracting alcohol from 1 ton of garbage would be about $2.00, and that about 25% of dried garbage, or about 5% of green garbage, could be converted into alcohol.

A summary of the results of the Morgan process, based on the experimental plant data, as compared with the results of the regular Columbus process, is shown in Table 129. The experiments were made by Messrs. C. P. Hoover and W. L. Melich, for Mr. T. D. Banks, Superintendent of the garbage reduction works at Columbus. This process has not as yet been conducted on a scale of sufficient size to determine its commercial value.

TABLE 129.—COMPARATIVE DATA OF GARBAGE REDUCTION AND MORGAN PROCESS OF OBTAINING ALCOHOL, AT COLUMBUS REDUCTION PLANT

Item	Reduction process	Morgan process
Percentage of grease from garbage...	3.33	3.11
Percentage of tankage from garbage..	8.22	8.10
Gallons of 90% alcohol per ton of garbage..........................	0.0	5.8
Percentages in tankage:		
Ammonia (NH_3).................	3.63	3.26
Potash (K_2O)..................	2.01	2.16
Tricalcium phosphate ($Ca_3(PO_4)_2$)..	4.94	4.46

Dr. Horst, of Chicago, has been experimenting with a chemical process for converting the cellulose of the garbage into dextrin or dextrose, but no useful data have yet been developed.

The Pan-American Feed Milling Company, of Kansas City, Mo., has been experimenting with the production of a stock food from garbage, but, as yet, no plant has been put into operation. However, an agreement has been made (1920), between this company and the Toledo Disposal Company, whereby an experimental plant

for making stock food is to be built adjoining the reduction works. The results of operation should be available during 1921.

D. PRODUCTS

1. Grease.—Garbage grease is a low-grade fat, used chiefly for manufacturing red oil, glycerines, and soaps.

Vegetable and animal oils are called " saponifiable " oils, to distinguish them from the mineral and essential oils. The saponifiable oils differ from other oils in their chemical composition, being compounds of organic acids with substances of the alcohol group. The most frequent representative of the alcohol group found in saponifiable oils is glycerine.

The composition of garbage grease is, of course, variable, but commonly consists of stearic, oleic, palmitic, and other fatty acids combined with glycerine in varying proportions.

These fats are found in oil seeds of plants and in animals. Garbage grease will contain, not only vegetable and terrestrial-animal oils, but also marine-animal oils. Stearin and palmitin have melting points of about 160° and 150° Fahr., respectively. Olein is softer, with a melting point of 25° Fahr. The melting point of the grease depends on the relative proportions of the three fats in the mixture.

In the industries, the methods of extracting oil may be grouped under three heads: (1) by rendering, that is, by boiling out with water; (2) by pressing; and (3) by using solvents. The vegetable oils are obtained bycrushing and then pressing the crushed material or treating it with a solvent. Thorp * states that extraction with a solvent " gives a larger yield of oil, comparatively free from gelatinous matter, but some resins and coloring matter may be dissolved, thus contaminating it. . . . . If the extraction is carried too far, the residue of crushed seed pulp has less value as animal food and is chiefly used as fertilizer or fuel." The press-cake from many vegetable oils is valuable as cattle food, because of the oil and proteids contained therein.

Animal oils and fats can be extracted by rendering, i.e., either by boiling with water to which a small quantity of sulphuric acid is added to promote the breaking up of the cell walls and thus liberating the oil; or by cooking in large digesters in direct contact with steam under pressure. As these oils are contained in animal cells, which putrefy soon after the animal is killed, the rendering must be done within a very short time, or the fat will become rancid and have a bad odor.

Garbage grease as ordinarily prepared for the market is a brown-colored soft fat. The usual tests for saponifiable fats should be applied,

* " Outlines of Industrial Chemistry."

including those for hardness, rancidity, and the saponification value. The test is a good indication of the purity of the grease. The saponification value is expressed by the number of milligrams of potassium hydroxide needed to saponify one gram of the oil, or, in other words, to neutralize the fatty acids. This value indicates the quality of the grease for soap making. A higher saponification value than necessary indicates that more alkali is required for the manufacture of the soap. In most oils and fats this value is about 193; that of garbage grease is usually about 188. Grease with higher values than these is not desirable for soap and candle making. For other special tests of the value of grease, the reader is referred to text books on that subject.

Table 130 gives the average analyses of grease at the Columbus plant.

TABLE 130.—AVERAGE PERCENTAGES OF IMPURITIES IN GREASE AT COLUMBUS REDUCTION PLANT

Percentages by weight

Year	Moisture	Impurities	Unsaponifiable matter	Free fatty acids
1911	2.69	0.244	2.44	*......
1912	1.97	0.205	2.99	*......
1913	2.53	0.125	2.84	*......
1914	1.52	0.131	2.91	*......
1915	1.56	0.196	3.37	*......
1916	1.11	0.46	3.54	*......
1917	1.025	0.732	2.830	27.512
1918	1.96	0.55	4.57	50.02
1919	2.29	0.52	4.51	*......

* Not reported

The following observations can be made quickly, and are useful in judging the value of a grease:

a. The turbidity, which indicates the presence of water or of oils which mix imperfectly;

b. The quantity of sediment;

c. The color;

d. The fluorescence or " bloom," which indicates the presence of mineral oils;

e. The odor, especially when warmed, which, for instance, may be fishy or rancid, if the grease is not thoroughly stable;

f. The taste;

g. The viscosity, which may be judged by suddenly inverting a test-tube or bottle partly filled with the oil.

On account of the presence of sediment and of some odor, garbage grease is frequently used for making cheap toilet soap, in which the impurities are obscured by the color and perfume in the soap. Contracts for the purchase of garbage grease generally limit the percentage of moisture and the unsaponifiable matter and impurities to 3%.

Fig. 114 is a diagram showing the monthly percentage recovery of grease at the reduction works in Washington, Cincinnati, Detroit, Cleveland, and Chicago.

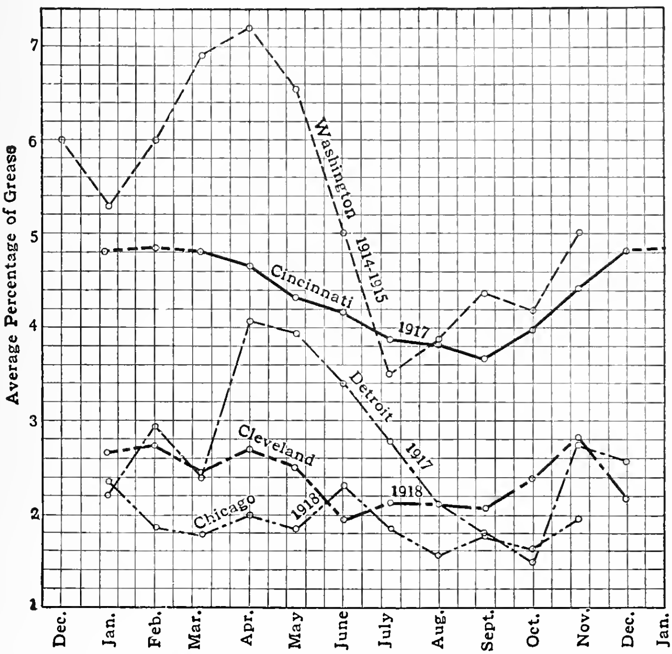


FIG. 114.—Average Monthly Percentage Recovery of Grease from Garbage in Several American Cities.

2. Solvents.—The extraction of garbage grease by a solvent requires the use of one that is volatile. Carbon bisulphide was first used by Mr. Jesse Fisher, in England, in 1843. As at present manufactured, this chemical is comparatively cheap, and, as it is heavier than water, it has certain advantages on account of storage; but its bad physiological effects on workmen, and the chemical action of impure carbon bisulphide on iron, have practically prevented its use. Carbon tetrachloride could be used, having the advantages of being non-inflammable and also heavier than water; but it is too expensive.

Petroleum naphtha is the solvent most frequently used at present. It is a product obtained by distillation from crude petroleum, and has a specific gravity of from 0.741 to 0.745. Under atmospheric pressure it vaporizes at from 160 to 210° Fahr. It is inflammable and explosive, and, under atmospheric pressure, has a boiling point of 160 to 210° Fahr. Petroleum naphtha is a mixture of hydrocarbons, and should be distinguished from so-called " solvent naphtha " or benzine derived from coal tar. Gasoline may also be used, but it is more expensive.

3. Tankage.—Tankage is ordinarily sold as a base or filler for artificial fertilizers. Its selling price is determined by its content of so-called " units " of ammonia, bone phosphate of lime, and potash. A unit of ammonia, for instance, is 1% of ammonia per ton of tankage, or 20 lb. A typical bill from a garbage reduction plant to a purchaser of tankage would be made up about as follows:

Car number ..... Shipped ..... (Date) ....., containing 38.5 tons of tankage valued as follows, from analysis:

Ammonia, 3.40% @ $2.50	$8.50
Bone phosphate of lime, 6.50% @ $0.10	0.65
Potash, 0.75% @ $0.70	0.53
Value per ton	$9.68
38.5 tons @ $9.68	$372.68

The percentage of moisture in tankage should be kept below ten. Methods of analyzing garbage or tankage for the above substances are given in Chapter I; reference should also be made to the reports of the Committee on Fats and Greases, of the American Chemical Society. Marketable fertilizers contain from 2 to 8% of ammonia, from 6 to 10% of bone phosphate of lime, and from 4 to 10% of potash, the remaining portion being a filler. The composition of the tankage should be varied to suit each particular soil. Before tankage can be percolated advantageously with a solvent, it should contain at least 10% of grease.

Table 131 gives the average analyses of tankage at the Columbus plant.

The fineness of the tankage is also a quality affecting its value. Tankage is sold either ground or unground, and is often sifted to reduce it to the proper degree of fineness.

In some reduction processes, the water from the separating tanks has been evaporated to a syrup (stick), to be added to the tankage before it is completely dried and finished. The tank-water contains a comparatively large percentage of fertilizing elements, and thus may enrich the tankage. It also is somewhat gritty, which adds to its

value, as it renders the tankage less fluffy and light; but the treatment of these waters is seldom economical.

TABLE 131.—AVERAGE PERCENTAGES OF CERTAIN COMPONENTS OF TANKAGE AT COLUMBUS REDUCTION PLANT

Percentages by weight

Year	Moisture	Grease	Ammonia	Potash	Tricalcium phosphate
1911	10.7	10.7	3.35	0.90	5.68
1912	10.2	2.0	3.50	1.03	7.16
1913	8.0	1.8	3.56	0.99	7.35
1914	3.1	1.2	3.58	0.78	8.08
1915	3.37	2.9	3.62	1.12	6.83
1916	2.85	3.3	3.89	1.39	7.99
1917	2.76	4.26	3.86	1.06	7.56
1918	3.39	....	3.77	1.08	7.94
1919	Tankage sold at flat rate on analysis guaranteed				
		thus:	3.50	1.00	7.39

4. Wastes.—The wastes from the reduction process are solid, liquid, and gaseous. All are capable of creating nuisances, chiefly the gases. The satisfactory operation of a reduction plant depends very largely on the method of handling these wastes. The solid wastes, such as rubbish, tin cans, etc., are the least objectionable. They are called "tailings," and can be disposed of like similar solid refuse.

The liquid wastes, ordinarily, are not large in quantity, and their proper disposal is not difficult. They are the floor washings, waste tank liquors, drippings from the presses, etc., and contain some grease and some ammonia. Analyses of the waste liquids from the plant of the Chicago Reduction Company are shown in Table 132.

In plants where the tank liquor is evaporated and the syrup added to the tankage, the quantity of liquid waste will be less. Where plants are near a large body of water or a system of sewers, the waste liquids can be discharged directly without much treatment. A properly designed catch-basin should be built to retain both the heavy settling solids and the lighter floating particles. If the plant is situated on a small stream in which the waste liquids would create nuisances, more complete purification must be provided. Special designs, similar to sewage treatment works, are required.

A satisfactory disposal of the waste gases is more difficult, owing to the necessity of confining them. They contain volatile organic com-

pounds, such as ammonia, phosphine, acetic acid, carbon dioxide, sulphur compounds, and partly burned carbohydrates, which create odors and are nuisances when discharged into the air near human habitations. During the last few years, methods of trapping and confining these gases have been greatly improved, and several processes have been developed for their final purification, or, more correctly, their washing and burning.

TABLE 132.—CHEMICAL ANALYSES OF WASTE LIQUIDS. CHICAGO REDUCTION PLANT. JULY 25, 1911

(Courtesy of The Sanitary District of Chicago)
Results in parts per million

Source of sample	Suspended Matter			Oxygen Consumed			Nitrogen		Chlorine	Alkalinity
	Total	Volatile	Fixed	Total	By soluble matter	By suspended matter	Organic nitrogen	Free ammonia		
Condenser water from naphtha plant	132	96	36	53	....	....	9.5	3.0	31	130
Water from washing tower for waste gases	88	76	12	184	....	....	10.0	6.8	33	82
Drain from garbage pile	4280	4000	280	8850	8790	60	1407	1.2	Excessive	2500

If the waste gases are carried to a wet well, those which are soluble will be dissolved and may be discharged into the sewer. The insoluble gases may be passed through a hot fire and deodorized by oxidation. If the gases are led to a high tower, from the top of which a fine spray of water is continually falling, some are dissolved when passing up the tower and much of the odor is removed. The insoluble gases, however, escape at the top. By heating, some of the insoluble sulphur compounds are changed to soluble sulphur dioxide, which can be removed by washing.

Insufficient attention to waste gases has been chiefly responsible for the objections to the reduction system.

5. Odors.—Objectionable odors at reduction works are due, partly to the garbage when it is stored temporarily at the plant until treated, partly to the fumes escaping into the open during the treatment, partly to the exposed tankage, and partly to the exposed liquids

discharged from the digesters and grease-separating tanks. The intensity or quantity of odor depends on the details of the process. Direct-heat driers, particularly, produce gases in quantities which are difficult to control.

To prevent the creation and diffusion of these objectionable odors, the works, as a first requirement, should be kept scrupulously clean. The operation should be arranged so that the freshly delivered garbage can be placed in the digesters at once, or within a very short time, and not left exposed in the open air to become foul.

Gases and vapors arising from digesters, as well as from presses, naphtha tanks, driers, and wherever odors from the cooked garbage may be generated, should be confined and discharged into pipes of diameters properly proportioned to carry away completely all odorous air ascending from each source. The draft into the hoods and the circulation through the pipes is best effected by a blower of ample capacity.

The odorous air thus collected from all places where it is formed should be delivered to proper places for a careful treatment. One such place may be below the grates of the furnaces at the plant, where the foul gases can be passed through the fires by forced draft and be burned by intense heat. If the quantity of this foul air is too great for the regular furnaces, an additional special furnace should be built to burn the excess, as the complete destruction of this foul air is generally imperative; or, it may be discharged into the rear pass of the boilers, and this may be sufficient to eliminate its objectionable character. Washing with water, and a proper control of the furnace temperature, may also sometimes be sufficient. Passing the foul air through a disinfecting chamber is generally less effective and more costly.

Practically all the objections which have been made to the establishment of garbage reduction works in the United States have been caused simply by the fact that the foul odors naturally emanating from them have not been suppressed by efficient means.

A noticeable improvement of the odor in a reduction plant may be gained by occasionally blowing compressed pure air from a jet (air washing) against the interior walls of the building, the surfaces of all apparatus within it, and even against the clothing of the attendants, which otherwise has been known to retain the odors for many hours. The use, also, of ozone has been proposed, but the additional expense of this material is rarely justified.

At the Barren Island reduction plant, Osborn and Klein made some investigations, on the elimination of odors, for the Committee on Street Cleaning of the Board of Estimate and Apportionment of

New York City, in 1915. The result of their work is summarized below:

It was found that the odors from the reduction plant came from the following sources:

1. The crude garbage delivered at the plant;
2. The tankage stored at the plant;
3. The vapors given off from hot materials during the process, when they are exposed to the air;
4. The vapors given off by the grease settling basins;
5. Odors given off from materials which sour or ferment and which accumulate when the plant is not kept in a cleanly condition;
6. Leaks in apparatus under pressure, where gases and vapors escape and so are not confined and deodorized;
7. The gases vented from the tops of the digesters;
8. Gases given off from the receiving tanks below the digesters when the latter are discharged;
9. The gases from the driers;
10. The dust in the drier gases.

The first six of these sources are considered as producing more or less local odors which could be controlled by proper upkeep, good ventilation, and the maintenance of the apparatus in a clean condition. Comments on the last four sources listed were made as follows:

7. The gases vented from the tops of the digesters are the most permeating odors from the reduction process. The volume is not so great as from the driers, and with proper treatment can be completely deodorized.

8. The gases given off from the receiving tanks, except for the air displaced, consist mostly of steam vapor, and can be condensed.

9. The gases from the driers are not as permeating as the digester gases, but, with direct-heat driers, the volume is large. These gases can be deodorized if properly and sufficiently treated.

10. The dust in the drier gases is carried in suspension. A large part can be eliminated by passing through a dust chamber, and all can be removed by scrubbing.

It is thus repeatedly reported that the odors from the reduction process, causing nuisance to the surrounding territory, come chiefly from two sources, viz., the gases vented and escaping from the digesters and driers. The greatest source of odors is from the direct-heat driers.

Regarding the digester gases, it was found that they contained alcohols, acetic acid, some volatile fatty acids, carbon dioxide, some of the essential oils, and sulphur compounds. There were also substances carried over mechanically by the steam. In solution there was 0.0067% mineral and 0.0035% organic matter: in suspen-

sion, 0.0016% mineral and 0.0106% organic matter. The water used for absorbing these gases sometimes had considerable odor, removable, however, by small quantities of chloride of lime. It was also found that heating the gases to from 700 to 800° removed all stinking odor.

Table 133 shows the effect of heating on the odor of digester gases, according to observations made in Chicago.

TABLE 133.—Effect of Heating on the Odor of Digester Vent Gases

Temperature in center of furnace, in degrees, Fahrenheit,	Temperature of gases, in degrees, Fahrenheit, at point where odor was noted	Nature of odor
40–350	40–118	Sweet, slightly nauseating, slightly irritating
450	144	Sweet; slightly acrid; slightly irritating
550	169	Not so sweet; acrid; slightly irritating
750	176	No sweetness; more acid and irritating
850	194	Acid; irritating; sulphur dioxide odor
950	201	Acrid; irritating; sulphur dioxide odor
1050	205	More acrid; irritating; sulphur dioxide odor very distinct
1150	230	Acrid; irritating; sulphur dioxide odor very distinct
1200	230	Acrid; irritating; sulphur dioxide odor very distinct

Regarding the drier gas, it was found that the odor could be completely eliminated by heating to a temperature of 1850° Fahr., and that all odor was removed by bubbling the gases through a quantity of water containing a calcium hypochlorite solution having about 1/1000 part available chlorine.

Tests were also made on the dilution of drier gases with air, with the following result:

Rate of Flow, in Cubic Feet per Minute		Dilution of drier gas to air	Intensity of drier gas odor in mixture
Drier gas	Air		
0.6	12	1 : 20	Very strong
0.2	12	1 : 60	Strong
0.031	12	1 : 400	Distinct

The results show that no reasonable amount of dilution with air is effective in causing the drier gas odor to become negligible.

As a result of these studies and investigations, the following recommendations were presented:

1. That immediate changes be made in the treatment of the insoluble gases vented from digesters through condensers, so as to deodorize them entirely, as the present practice of discharging into the boiler furnace does not deodorize them.
2. That special attention be given to keeping all tanks containing digested garbage, or garbage in the process of digestion, free from leaks, and that equipment not absolutely free from leaks when under pressure be kept out of service until repairs are made.
3. That gases shall not be permitted to escape at the time of opening digesters.
4. That special attention be given to all condensers to insure sufficient water being used, and at a temperature that will condense all the steam and take up all soluble gases.
5. That the present drier plant be constructed or changed so as to prevent leakage and reduce the volume of gases to be treated.
6. That all gases given off from the driers shall be scrubbed and deodorized thoroughly before being allowed to escape to the atmosphere.
7. That the scrubber now installed be replaced or reconstructed, to enable the volume of gas passing through it to be washed or scrubbed thoroughly.
8. That the water supply at the plant be increased, and, where necessary, pumps be duplicated to insure sufficient water for condensing and scrubbing of gases at all times.
9. That the pumps be of a type that will insure the required quantity of water being delivered; and fitted with meters to show the quantity used.
10. That the works and grounds be kept at all times in a cleanly condition.
11. That the city at all times should have inspections made, to determine the manner in which the work is being done.

It was also stated that, to obtain satisfactory results in the scrubbers, the temperature of the gas should be reduced to 100 or 110° Fahr., and the velocity should be at the rate of 300 to 350 ft. per minute, the quantity of water required depending on the quantity and temperature of the gases to be scrubbed.

The cost of the necessary changes to eliminate the public nuisance from the reduction plant was estimated to be about $100,000, or approximately $50 per ton capacity.

It should be stated, further, that this investigation was carried out at a reduction plant using the cooking process, and built on an island at a considerable distance from dwellings. Under other conditions, still greater attention to plant cleanliness and sources of

odors classed as local would be required where the location and environment are more critical.

E. DESIGN AND CONSTRUCTION

The design of a reduction plant requires a study of its various functions, the machines used for each process, and the grouping or arrangement of its parts. These parts are described below. They should be designed to fit the local conditions for each plant. Much of the machinery included is manufactured by certain firms, and stock articles can be purchased. The general arrangement of the parts can be best ascertained from the descriptions of existing plants. Special designs for each location, however, are almost always required.

1. Buildings.—Owing to the fire risk, the buildings should be fire-proof. The acids in escaping gases act on galvanized iron, and therefore it is not permanent. Brick, stone, or dense concrete with smooth surfaces well rubbed down, are the most suitable materials. It is generally desirable to give the buildings and grounds an attractive appearance. The slight additional cost is generally fully justified.

Proper facilities for receiving the garbage at the plant depend on the method of delivering it. Provision should be made for rapid handling, with as little hand labor as possible.

At Columbus and Cleveland, the garbage is sent to the plant in side-dumping tank cars. The receiving buildings contain elevated tracks for the cars. Below the tracks there is a storage bin with sloping bottom, and covered drains. A conveyor extends along the bottom of the hopper. The cars are dumped with a gear. After being dumped, the garbage is raked upon the conveyors by laborers, and the tin cans are picked out. The free water flows away in a drain for subsequent treatment.

At Chicago the garbage is delivered to the plant in removable wagon boxes. These are picked up by a crane and emptied into elevated storage bins of reinforced concrete. These bins have hopper bottoms fitted with valves, and discharge by gravity upon conveyors. The openings and valves must be of ample size to prevent clogging. Before the empty wagon boxes are again set on the wagon bodies, they are washed by dipping them into a tank of hot water containing creosote.

At the Barren Island reduction plant conveyors extended from the dock into the digester building. The garbage was transferred by grab-buckets from the barges to the conveyors.

At smaller plants the wagons dump directly into concrete hoppers from which the garbage is raked upon the conveyors.

Ample capacity of the buildings is essential, as overcrowding the plant reduces its general efficiency and curtails the opportunities for thorough cleaning. The apparatus receiving garbage should be enclosed wherever possible. A weighing scale should be placed at the entrance to the plant.

2. Conveying Machinery.—In modern reduction works, the garbage, tankage, grease, etc., are handled mechanically. A large number of conveyors and other apparatus are required. The surfaces, links, corners, and adjacent spaces about this machinery become covered or filled with bits of garbage and its juices, and these decompose and produce odors. All such apparatus should be arranged in accessible places, with ample facilities for washing and cleaning.

The raw garbage is generally handled in trough or scraper conveyors, which consist of rectangular sheet-steel troughs in which travels an endless belt of vertical steel plates or scrapers. The plates fit loosely in the trough, and are suspended from a link belt which travels on rollers running on rails on each side of the trough. The garbage is thus carried or pushed along by the plates. Openings can be left in the bottom of the trough for discharging the garbage at selected points. It is comparatively easy to clean a conveyor of this type.

Cup conveyors have been used for this service, but are not generally satisfactory. Within the plant, traveling belt conveyors, and also screw conveyors, are used for tankage. The latter are particularly useful for moving finely divided wet material. The design of conveying machinery should provide for access to every point for cleaning.

3. Crushers.—At plants where the garbage is to be dried without prior cooking, it is good practice to break it up in a crusher or grinder. For this service a number of machines are on the market. A rotary or gyratory crusher with small clearance was used at Chicago with satisfactory results. A rotary crusher, similar to that used for breaking up coal, may also be used.

4. Digesters.—In cooking garbage, acids are set free and may attack metals. Therefore tanks and digesters are destroyed, if not especially designed to withstand corrosion. The specific acids formed depend on the composition of the garbage, but all contain a mixture of organic acids, such as acetic acid. These are especially active at the temperature which must be maintained in the digester.

As ordinarily built, garbage "cookers" or digesters consist of vertical steel cylinders with openings at the top and bottom for receiving and discharging garbage, steam, water, and gases. Their purpose is to break up the cellular structure of the garbage, so as to promote the separation of liquids and grease. The main feature of the

process is the cooking with live steam, but there are different appurtenances for mixing the steam and garbage, stirring the mixture, and drawing off the products, each designer following his own preference.

At the Cleveland reduction plant the digesters are 14 ft. high and 4 ft. 6 in. in diameter. Steam is turned in at the bottom, and the cooking continues for six or seven hours under 70 lb. pressure. When the cooking is done, the steam is shut off at the bottom and turned in at the top, the pressure driving off the free water and some of the grease through a draw-off pipe at the bottom.

At the Schenectady plant, steam is admitted at the bottom of the digesters through a ring of pipe resting on the bottom, and is discharged through numerous holes a few inches from the inside of the shell.

At Columbus each digester is 7 ft. in diameter and 14 ft. high, and is made of $\frac{5}{8}$-in. steel plates. The inside is lined with cement and tile, $1\frac{1}{4}$ in. thick, to protect the digester from wear by the agitation of the gritty material during the boiling, and to resist the action of the acids set free. The diameter of the inlet at the top is 18 in.; that of the outlet at the bottom is 16 in. A nozzle for the admission of steam is tapped into each side of the outlet casting. The steam, entering both nozzles at once, spreads and circulates thoroughly through the garbage.

Experience indicates that steel digesters without a lining last only about two years before extensive repairs or complete replacement are necessary. Attempts have been made to line them with wood, but eventually this also gives way, or allows the iron to be attacked. The presence of the wood lining also makes repairs difficult. Specifications now commonly require that digesters shall be lined with vitrified brick, tile, or—less effectively—with cement or concrete. A digester costs from $600 to $1000. (1914.)

5. Presses.—After the cooking has been completed in the digesters, the mass is pressed in order to separate the water and grease from the solid matter. Presses of three types are in use; the hydraulic press, the roller press, and the steam press.

The earliest plants had the hydraulic press. This consists of a vertical piston carrying on its lower end a heavy casting, about 4 ft. square, running in guides. The cooked garbage, stored in receiving tanks under the digesters, is drawn out on flat cars of the same cross-section as the piston head. The operation of charging is as follows: First, there is placed on the bottom of the car a square piece of lattice work or a false bottom, made of laths, and on this is spread a piece of burlap. On top of the burlap is set a square wooden frame about 4 in. deep. The digested garbage is run on the burlap until the frame

is full; the latter is then removed and the mass is bound up in the burlap. Another piece of lattice work is then placed above the burlap bag, the frame is replaced, and the operation repeated. In this way each car is loaded to a height of about 8 ft. The car is then run under the press, and the material is pressed down to a thickness of 2 or 2.5 ft. The water and grease which have been squeezed out on the floor are conducted in drains to a pump well or settling basin. For loading one car about twenty pieces of lattice work and about 20 yd. of burlap

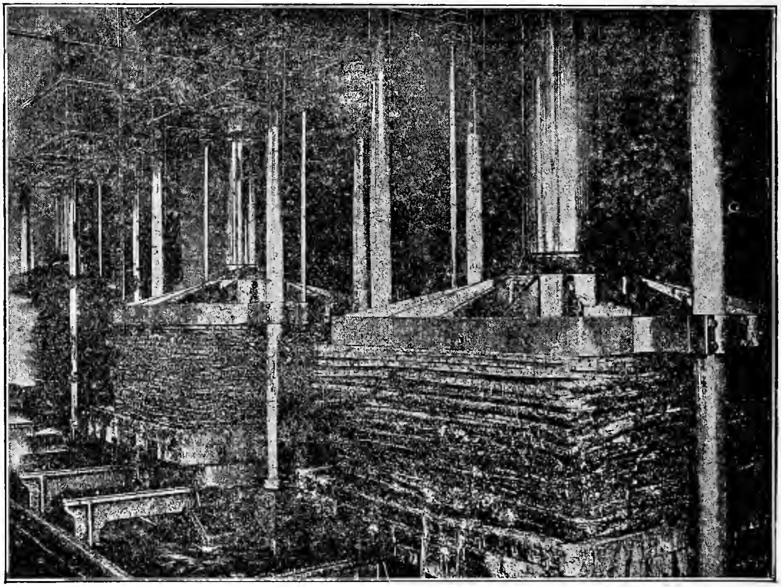


FIG. 115.—Pressing Grease and Water from Cooked Garbage, New York. (From "The Disposal of Municipal Refuse," by H. de B. Parsons.)

are used. The lattice work lasts only a few days. Two men are required to load a car. The work is dirty and unpleasant, because the hot cooked garbage spatters about considerably, and quantities of steam and vapor are given off. The presses operate under a pressure of from 40 to 100 lb. per square inch. The process is illustrated in Fig. 115.

The continuous-roller press permits of cleaner operation, and requires less labor. Typical roller presses are used at the Columbus reduction works, from designs by Mr. Charles Edgerton. They are enclosed in cast-iron covers, about 28 ft. long, 7 ft. high, and 3 ft. wide, and are practically gas-tight. Each press is connected directly with the bottom of a receiving hopper, which stands under and serves

four digesters. There is an upper and a lower conveying apron, the upper one being made up of $\frac{1}{2}$-in. steel strips riveted to heavy forged-steel chains. This apron forms the bottom of the receiving hopper, and, as it moves, the material is carried through the feeding rolls and is discharged on the lower apron. The upper apron occupies the rear half of the machine (Fig. 116), the lower one passes through six cast-iron rollers, set in pairs, one above the other, and at the front end of the machine. It is composed of perforated plates, $\frac{3}{8}$ in. thick, riveted to forged-steel chains. The rollers are 28 in. in diameter, and are controlled by heavy steel springs, by which the pressure may be increased or decreased, depending on the quantity of material to be pressed. These presses are constructed of cast iron, wrought steel, or cast steel, and are fitted with renewable wearing strips, take-up boxes, and cleaning brushes. The pressed material is discharged at the front of the press into a conveyor. The water and grease flow out of the sides into floor drains leading to catch-basins.

The steam press, devised by Mr. Irving Blount, is a more recent development, and was used at the Barren Island reduction works. It is constructed of heavy steel plates, and comprises a center cylindrical section having a perforated internal lining, and two slightly coned end-cylinders, also with perforated lining. The two end pieces are connected with the center cylinder by heavy hinges at the top, and are closed tightly with heavy bolts extending around the circumference. When closed, the press is filled with material from the receiving hopper. Live steam at high pressure is applied, and drives out the water and free grease through the perforated lining into pipes leading to catch-basins. When the pressing has been completed, the two coned ends are disconnected from the center cylinder, and the outer ends are swung around the hinges. This opens the press so that the pressed material can be discharged on the floor and scraped upon a conveyor. If the press is set vertically, only the lower end is hinged, and when it is opened the material drops to the floor.

In smaller plants, the pressing is sometimes done in digesters, through a perforated false bottom. A continuous screw press is also suitable for handling relatively small quantities of material. Pressing in digesters requires about two hours.

At the Chicago reduction plant, screw presses were used. These consist of a long pipe or cylinder within which is a revolving screw. The cylinder is perforated along the bottom, and fitted with small steel arms which fit the threads of the screw. The screw revolves continuously, pressing the material between its blades and the steel arms, and forcing the liquor out through the perforations in the cylinder.

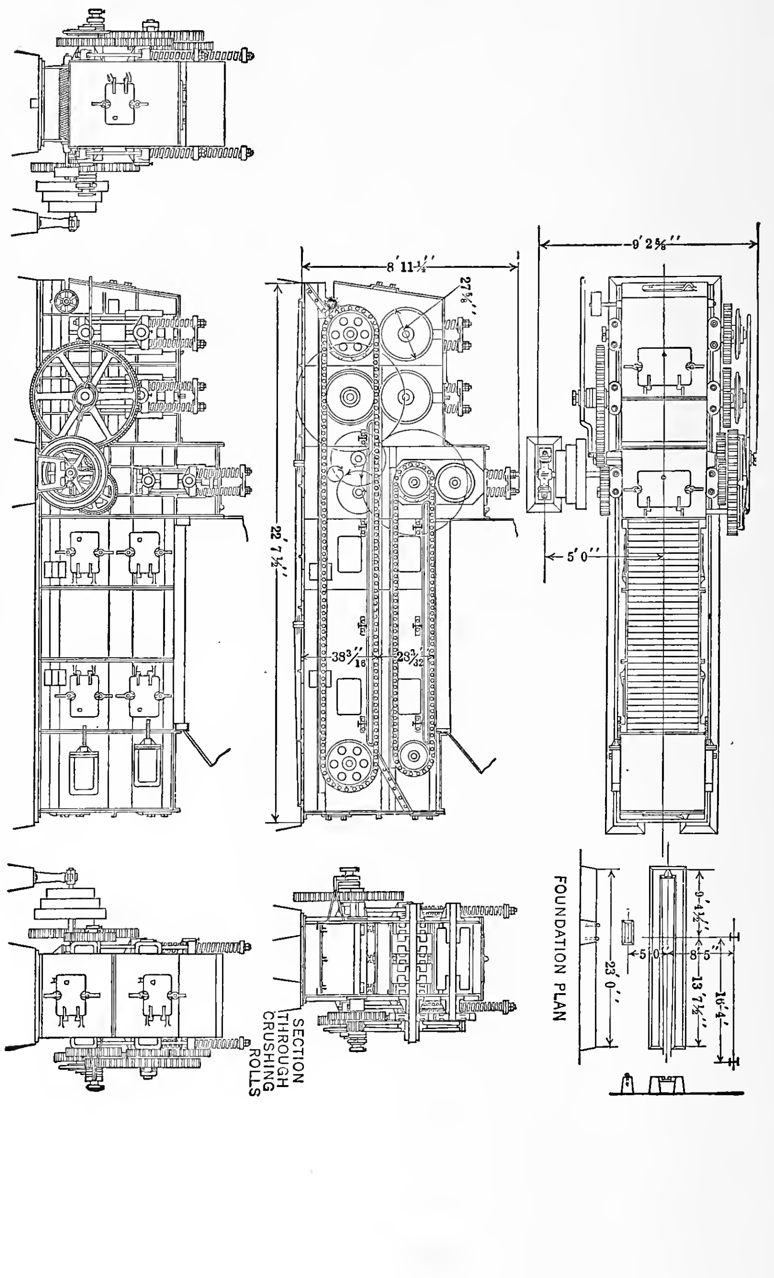


FIG. 116.—Edgerton Continuous Roller Press.

The moisture content of the material after pressing, is from 50 to 65%.

The liquid, called "stick," after leaving the presses is sometimes reduced and thickened by evaporation, and is added to the tankage to enrich it.

6. Driers.—The methods of drying are by direct or indirect heat. Direct-heat drying requires long cylindrical drums fitted inside with blades which turn the material over and carry it through the drums as it revolves. A blast of hot air is blown continuously through the drum. The temperature of this air is ordinarily from 300 to 400° Fahr. The escaping air contains foul-smelling gases, and must be purified. Its relatively large volume makes purification expensive. It is also found at times that the temperature of the air becomes excessive, thus causing some of the grease to be burned and some of the ammonia to be driven off.

As the margin between the economical temperature required for drying and that at which the grease burns is slight, the grease recovery with direct-heat drying may be slightly less than with indirect heat.

Indirect-heat drying also requires long revolving cylindrical drums; but, as these are steam-jacketed, a more uniform temperature results, and there are smaller volumes of air and steam to care for. The danger of burning the grease is also reduced by the separation of the garbage from the hot steam, and by the steam temperature not greatly exceeding 212° Fahr. This method, however, is somewhat more costly than drying with direct heat.

The design of the machinery for drying is important, for several reasons. A sufficient and proper equipment is required in practically all types of plant, as this may be the chief source of odorous gases. At the Barren Island plant, it was estimated that 175,000 cu. ft. of gas per minute are given off from the driers of the direct-heat type.

Two types of driers are used: The direct-heat and the steam-jacketed drier; and of each of these several designs are on the market. A direct-heat rotary drier consists of a single steel shell in which the hot furnace gases come in direct contact with the material to be dried. Near the inlet end is a suitable furnace for generating heat from coal, oil, gas, or other fuel. The revolving steel cylinder is slightly inclined from the horizontal. The hot furnace gases and the wet material enter at the same end and pass through, the wet material being thoroughly agitated and mixed with the gases by the lifting action of steel angles and lugs placed inside the cylinder.

Such driers are built as large as 5 ft. in diameter and 40 ft. long. They are used for drying crushed garbage in plants where the cooking process is not used. There is danger of burning or charring some of

the grease and the fertilizer materials, although this danger is reduced somewhat by first bringing the hottest gases into contact with the wettest material.

A steam-jacketed rotary drier consists of an inner shell surrounded by a steam-jacket and fitted inside with lifting angles. The heat for drying comes from the steam through the inner shell. The heat is augmented by blowing hot air through the shell. A radiator of steam coils is set in a brick house at the rear end of the drier, and a small cast-iron fan blows air through the coils and into the drier. At the discharge end of the drier an exhaust fan forces the saturated air to a purifying apparatus. The material to be dried is fed into the drier by a special conveyor, and passes through it by gravity, the drier being slightly inclined. The drying process consumes more time with this than with the other type.

An intermediate form consists of two concentric steel cylinders. The inner cylinder acts as a flue for hot furnace gases, and the space between it and the outer cylinder is used for the passage of the material to be dried. The two cylinders are firmly connected by heavy cast-iron braces, and both revolve together. At the end farthest from the furnace, the hot gases, now partly cooled, pass into the annular space and return to the furnace end, passing through the tumbling material. This method of drying decreases the danger of burning. A similar type consists of a cylinder mounted within a brick chamber. Hot gases enter the chamber surrounding the cylinder, and are drawn into the latter through openings cut at intervals in its shell. The material to be dried passes through the cylinder.

Still other types are used. For small plants, a vertical cylinder, about 6 ft. in diameter and 6 ft. high, is sufficient. This may be set in the brickwork of a furnace; or the drying may be accomplished by steam working under a vacuum. Another device provides a porous hearth in a concrete box. Heated air is driven by a fan into a space below the hearth, and forced through the pores into and through the material to be dried, the latter being placed on the upper end of the hearth.

With these drying processes, the moisture content may be reduced to about 10%. Secondary driers may be required to dry the tankage after percolation.

7. Separators.—There are several designs of basins for separating the grease from the water and other impurities. The simplest are shallow rectangular tanks in which the grease rises and floats above the water, whence it is pumped to a storage tank. A more elaborate arrangement is a battery of vertical steel tanks connected in series. The floating grease overflows from the first tank into the second, and

so on through all the tanks, the largest quantity being collected in the last tank. Treating tanks are also sometimes used. These are either rectangular or circular, and the grease is heated in them by steam coils to remove the impurities. These tanks should have hopper bottoms, to facilitate cleaning. The grease is pumped from them into storage tanks for shipment.

8. Evaporators.—The so-called tank-water which remains in the grease-separating tanks contains enough valuable solids in solution to make it pay to recover them, under certain conditions. This is done by evaporation. Modern evaporators operate with steam (often exhaust steam) under a vacuum.

One type of evaporator is made up of a vertical, cylindrical shell of cast iron or other suitable material. At the bottom is a heating surface of tubes, and above is the vapor space. The steam circulates within the tubes, and the liquor outside of them.

At the Columbus works, triple-effect evaporators are used. Each is 8 ft. in diameter, and the total heating surface is 2554 sq. ft., made up of No. 14 (old gage) brass tubes, $1\frac{1}{4}$ in. in diameter. These evaporators can concentrate 1500 gal. of tank water per hour from 7° to 22° Baumé, using exhaust steam at a pressure of 5 lb., and a vacuum of 25 in. in the third-effect evaporator. Condenser pumps, sight holes, and other appurtenances are required. The concentrated syrup is drawn off by a Magma pump, and mixed with the tankage. Other satisfactory types of evaporators are in the market.

9. Percolators.—Percolators or extractors are used to treat the dried material with a solvent and thereby recover the remaining grease. It is necessary to have an intimate mixture of the material with the solvent, and a provision for drawing off the solvent and grease with as little of the solid matter as possible.

Percolators are ordinarily vertical, cylindrical, iron tanks, from 8 to 10 ft. high and from 4 to 7 ft. in diameter, the garbage being charged through an opening in the top. The solvent is pumped in, is allowed to percolate through the material, and is later drawn off with the grease. An appreciable quantity of the solvent remains, but this is recovered by injecting steam into the percolator, which vaporizes and drives it off.

To complete the extracting process, the following apparatus are required. The grease and solvent flow from the percolator to a treating tank in which steam coils heat the liquid sufficiently to vaporize the solvent and leave the grease in the tank. The vaporized solvent then passes through a condenser, where it is recovered. The loss of solvent may amount to as much as 2.5 gal. per ton of material treated.

With the Cobwell process, at New Bedford, the loss of solvent is said to be from 2 to 5 gal. per ton of garbage treated.

The Columbus reduction plant was first built without percolators. A percolating plant, costing approximately $20,000, was added subsequently. During 1912, 203.5 tons of grease were recovered by percolation, amounting to 1.82% of the total garbage reduced. The price received for the grease was $16,890, or 4.14 cents per pound. The cost of operating the percolating plant during the year was $4,601.97, including labor, fuel, gasoline, and supplies. The records of grease and tankage recovered at the Columbus plant are shown in Table 134.

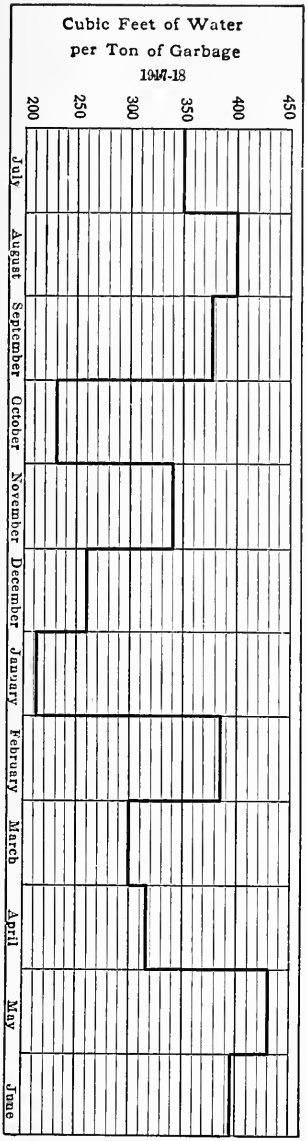
TABLE 134.—GREASE AND TANKAGE RECOVERED AT COLUMBUS REDUCTION PLANT

(From *Engineering News-Record*, Nov. 18, 1920.)

Year	Tons of garbage reduced	Percentage of total garbage reduced	
		Grease	Tankage
1911	17,534	2.227	13.37
1912	18,789	2.721	11.64
1913	20,711	2.697	10.10
1914	21,629	2.744	8.10
1915	22,909	2.214	10.031
1916	21,861	3.076	10.307
1917	17,127	2.261	10.214
1918	15,630	2.164	10.258
1919	18,126	1.942	8.60

10. **Screens.**—Generally, screening is the finishing process for the tankage. Overhead revolving screens, having about five openings per square inch, separate all large lumps, nails, cans, etc., from the tankage. Sometimes iron particles are withdrawn on magnetized belt conveyors. The screened product is taken to a storage room. In the West the tankage is sometimes burned. Under favorable conditions of burning, 6 tons of tankage have been found equivalent to 1 ton of coal.

11. **Water Supply.**—A comparatively large volume of water is required in the operation of reduction plants. The quantity used at the Los Angeles plant (Cobwell system) is shown on Fig. 117, and averages from 200 to 300 cu. ft. per ton of garbage reduced. In this plant the condenser water is cooled and used over and over again.



Year	1915-1916	1916-1917	1917-1918
Total Tons of Garbage Treated	44,999	50,036	46,786
Average Tons Treated per Day	121	137	128

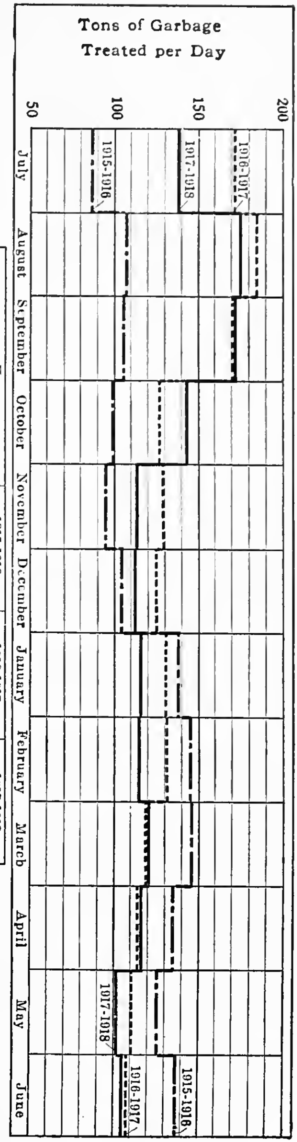


FIG. 117.—Quantity of Garbage Treated, Los Angeles, Cal., and Quantity of Water Required per Ton of Garbage, for Year Ending June 30, 1918.

At Columbus, where this is not done, the water consumption is estimated and given at 1000 cu. ft. per ton of garbage.

12. Storage.—Pending shipment, there must be ample facilities for storing grease and tankage. The grease is pumped to overhead tanks, from which it can flow into tank cars. At the Columbus plant, with a daily capacity of 160 tons of raw garbage, four grease storage tanks are provided, with a total capacity of 15,000 gal. The plant at Spectacle Island, Boston, has storage capacity for 250 tons of grease per twenty-four hours, or 50,000 gal.

Storage for tankage is ordinarily provided on an upper floor in order to facilitate shipping in bulk in box cars. Some plants have a special warehouse. At the St. Louis plant, with a capacity of 150 tons of garbage per twenty-four hours, the warehouse is 36 by 128 ft. in plan.

13. Shipping Facilities.—Special switch tracks should be provided for shipping the grease and tankage. There should also be scales, and a laboratory for sampling and analyzing the products, as their value depends on their composition.

14. Accessories.—The accessories at a garbage reduction plant include a boiler plant, with all appurtenances, a good fire-fighting system, an office, and a laboratory with instruments. Scales, roadways, electric lighting, etc., are also necessary. The boiler equipment at a number of plants is shown in Table 135.

TABLE 135.—Capacity of Boilers at Reduction Plants

Plant	Rated capacity of plant, in tons per day	Boiler horse-power	Horse-power per ton
Barren Island, N. Y.	2000	5320	2.6
Staten Island, N. Y.	2000	3000	1.5
Boston, Mass.	250	1750	7.6
Los Angeles, Cal.	175	900	5.1
Chicago, Ill*	500	506	1.0
Columbus, Ohio	160	700	4.4
Cleveland, Ohio	240	700	3.0
Schenectady, N. Y.	40	250	6.2

* No digestion, simply drying.

The chimney must be adequate for both the boilers and the cleaned gases from the digesters, driers, and other parts of the plant.

Reduction works require special attention in regard to the elimina-

tion of odors of the waste products, particularly the waste gases. Up to the present time, the problem has been difficult of satisfactory solution by the constructive means generally used.

F. OPERATION

The operation of a reduction plant requires both technical skill and business ability, the latter being necessary to market the products. At large plants a chemist should be employed. Compared with other methods of disposal, a higher grade of skilled labor is required, because of the complex mechanical and chemical nature of the process. For successful operation it is necessary to watch the cooking process, to make sure that a digester is not emptied before cooking is complete; the drying must be properly regulated to avoid loss by burning; and the percolation must be carefully controlled to avoid the excessive loss of solvents. There must be strict discipline, in order to avoid danger of fires; and careful attention to the details of maintenance and operation is required, if odors are not to exceed an allowable minimum. Frequent inspection by the Health Department is advisable.

Owing to the fact that reduction works have been in the hands of private corporations and contractors, information regarding the details of their operation, as well as cost, have not been as available as have those of other methods of disposal. Cleveland has built and operated reduction works by its own officers, who, in their annual reports and otherwise, have recorded the best published information available on the operations of such plants. Columbus, likewise, built and operated a municipal plant, from which detailed information is available. Other cities now operating their own plants are Dayton, Akron, Schenectady, and Chicago. Washington has recently taken over such a plant from the contractors, and will add still more to our knowledge concerning the best details of operation.

From the annual report for 1919 of Mr. Alex. Bernstein, Director of Public Service in Cleveland, we find that the grease content increased from 2.36% in 1918 to 2.55% in 1919, showing a slight relaxation in the conservation movement.

Table 136 is a comparative statement of the operation of the Cleveland reduction plant for the years 1915 to 1919.

In Chapter XII will be found a statement of the crew and equipment required to operate the works, as well as the cost.

TABLE 136.—OPERATIONS OF THE CLEVELAND REDUCTION WORKS FOR 1915, 1916, 1917, 1918, AND 1919

(From Annual Report, Director of Public Works, 1919.)

	1915	1916	1917	1918	1919
Garbage collected, in tons	62,357	60,717	56,121	57,754	60,932
Tankage recovered, in tons	6,879	7,037½	6,341	6,329	7,093½
Grease extracted, in lb.	3,731,770	3,819,325	3,071,092	2,726,786	3,116,797
Earnings—Reduction	$223,145.14	$302,427.16	$292,012.96	$437,344.01	$295,680.69
Expense—Reduction	151,503.31	155,584.80	191,001.09	265,243.29	238,202.73
Earnings—Net	$71,641.83	$146,842.36	$101,011.87	$172,100.72	$57,477.96
COMPARISON PER TON OF GARBAGE COLLECTED					
Earnings—Reduction	$3.58	$4.98	$5.20	$7.57	$4.85
Expense—Reduction	2.43	2.56	3.40	4.59	3.91
Net earnings—Reduction	$1.15	$2.42	$1.80	$2.98	$0.94

G. PLANTS BUILT AND RESULTS OBTAINED

Available records indicate that forty-five reduction plants have been built in America, but, of these, only about twenty were in active use in 1918.

Boston, Los Angeles, Cincinnati, Pittsburgh, Detroit, Toledo, Philadelphia, Bridgeport, and New Bedford dispose of their garbage by reduction under contract. Schenectady, Columbus, Cleveland, Dayton, Chicago, Washington, and Indianapolis have their own plants, and at Rochester and Syracuse works are under construction. The New York plants on Barren Island and on Staten Island have been at present abandoned.

Brief descriptions of a few of these plants follow:

1. New York City.—The original garbage reduction plant was built in 1896 on Barren Island, about 11 miles in an air line from the City Hall; and, with changes, additions, and enlargements, it treated garbage from the Boroughs of Manhattan, The Bronx, and Brooklyn from that time until 1917. In that year a new plant, using the Cobwell system, was put into operation on Staten Island, under a contract for five years. Fig. 118 shows the general layout of the plant, and also longitudinal and cross-sections. The following

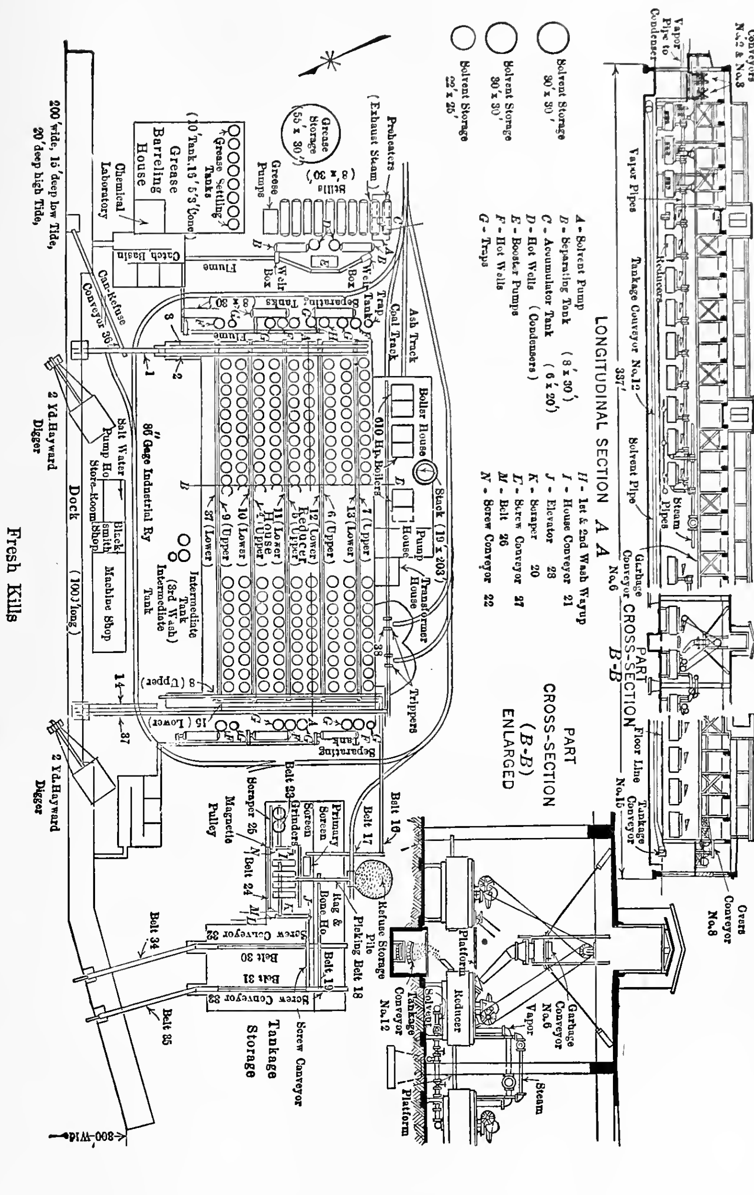


Fig. 118.—Garbage Reduction Plant, Borough of Richmond, New York City.
(From *Engineering News-Record.*)

description is abstracted from the *Engineering News-Record* of March 21, 1918:

"The plant is located on Fresh Kills, lower Staten Island, Borough of Richmond, New York City. There is no railroad connection. All materials used must be brought in or taken out by boats. The materials received are 1500 tons of garbage per day, the necessary solvent, and coal for 3000 h.p. of boilers. The products shipped are grease, tankage, and such by-products as bottles, cans, bones, and rags. To accommodate the shipping, a dock 1000 ft. long has been provided. The designers of this plant had about 57 acres of unimproved practically level land at their disposal, so the conditions were ideal for the construction of a plant for the economical and rapid handling of the garbage, the various materials required for its treatment, and for the disposal of the final products.

"The plant was put in operation late in 1917. It was designed to meet the conditions of a contract between the Metropolitan By-products Co. and the City of New York for the disposal of all the garbage from the city, excepting a part of Queens Borough and Staten Island, for a period of five years, the city reserving the privilege to buy the plant at the expiration of the contract. The nominal capacity of the plant is 1500 tons a day. It is operated in three shifts of eight hours each.

"While in transit in 150- to 300-ton barges the garbage is covered with large water-proofed tarpaulins which are washed and spread out to dry each trip while the garbage is being unloaded.

"A 2-yd. clamshell bucket transfers the garbage from the barges to a large receiving hopper placed on shore and located directly over a picking or sorting conveyor. A feeder is provided under this hopper to insure an even layer of material on the conveyor, which is essential to the preliminary sorting of certain materials. This feeder consists of a cast-iron box in which two intermeshing paddle wheels slowly revolve, allowing the proper amount of material to pass through.

"The picking conveyor consists of a series of overlapping steel pans mounted on two strands of chains that are in turn mounted on self-oiling rollers. Men are stationed on both sides of this slow-moving conveyor whose duty it is to remove (as far as possible without stirring) all glass, crockery, cans, large rags, wood and other substances that might clog the conveyors or machinery. It is here that the milk and wine bottles are recovered and placed in boxes or barrels, while worthless broken crockery, sticks, etc., are thrown into a chute that leads to a dump car below. The empty cans are separated and when a boat load has accumulated they are shipped away. It is interesting to note that the tin is recovered from the cans by a bath of chlorine gas. The gas is condensed and used in the dyeing of silk. The cans are then melted and cast into sash weights.

"From the picking conveyor the green garbage is fed to the system of conveyors installed inside the reducer house. These conveyors, eight in number, are made alike in so far as duplication is possible. Each one consists of a double strand of heavy drop-forged chain between the strands of which are mounted, at intervals, steel plate flights of scrapers. These scrapers run in a

water-tight trough in which are located slide gates of the rack-and-pinion type. The gates are all of the same pattern, whether for feeding down to the reducers or from one conveyor to another.

"The conveyors are so arranged that by the proper manipulation of the gates the garbage can be directed to any one of the 199 reducers located under the conveyors. The conveyors are driven by electric motors—the drives being alike, so that one spare part of each kind suffices for any. Conveyors 2 and 3 are in duplicate, so that any mishap to either will not tie up the plant. Conveyors 8 and 9 are called the 'overs' conveyors, for, as their name implies, they are so placed that they will catch any material that might run over the openings, or be left over after filling the reducers when using conveyors 4, 5, 6, or 7.

"The main or reducer building is a one-story structure of concrete, with brick-filled side-walls, covering an area 160×337 ft. Space is allowed for 10 rows of reducers, 24 in a row, or 41 more than the present installation. The reducers are elevated a few feet from the floor, to accommodate the necessary pipe lines, traps, etc., as well as to facilitate the discharging of the finished product onto a belt conveyor placed in a pit between two rows of reducers. There are two platforms running the length of the house. One platform is in front of two lines of reducers and gives access to all gages and sight glasses. The other platform is a little higher (just on a level with the reducer top) and gives access to the sample holes and spouts for filling in the green garbage. These platforms are made of 2×4-in. stuff laid flat with about $\frac{1}{2}$ in. between, and are the only wood in the building.

"Each group of 24 reducers has its separate crew of men and its own vapor and steam lines, trap tanks, condensers, and separators. Furthermore, the piping and valves are so arranged that any one reducer can be out of commission without affecting the operation of the others.

"The reducer is the central feature of the disposal process, known as the Cobwell system, which was designed by the C. O. Bartlett and Snow Co., Cleveland, and consists of a cylindrical steel shell whose height is about one-half the diameter. The bottom and sides of the reducers are double-jacketed and so arranged that live steam at about 100 lb. pressure can be admitted to the jacket without coming in contact with material inside the reducer. A center spindle is located on the vertical axis of the reducer, on which is mounted a pair of stirring paddles. This spindle is revolved by means of a pair of bevel gears and shafting located on the top of the tank and driven by means of a tight and loose pulley from an electric-motor-driven line shaft which serves 24 reducers. A single reducer holds about 5 tons of green garbage and is filled in from five to fifteen minutes.

"When the charging of a reducer is completed, the charging door is clamped down, and solvent is introduced until the mass is just covered. Steam is then turned into the steam jacket, the agitators are started, and the valves to the vapor line opened. The vapors are carried to a condenser, where the solvent is separated from the water and returned to the system for further use. Sea water is used for condensing, and is returned to the bay. It is interesting to note that the water vaporizes at a lower temperature when evaporated with a solvent than otherwise. Cooking is continued until the garbage is completely

dehydrated and the solvent goes to the condenser free of water. During the process of dehydration, more or less liquid, sometimes containing such light substances as corks, is carried over, hence it is necessary to introduce a large trap tank that can be drawn off from the bottom.

"The dehydrating operation requires about seven hours, at the end of which time the solvent contains a large amount of grease which has been liberated from the garbage. The reducer is provided with strainers in the bottom through which the liquor containing solvent and grease is then drawn to a still or treating tank, in which the solvent is recovered by distillation. The reducer is then filled again with solvent and drawn off as before, and even a third time—the three washings requiring an average of 45, 90, and 120 minutes, respectively.

"The separation of the grease from the solvent is all done in one still house in which are located 10 stills that can be used interchangeably. The stills consist of cylindrical steel tanks, 8 ft. in diameter and 30 ft. long, laid horizontally, in which is located a nest of small pipes for the admission of steam, the steam never coming in contact with the material to be distilled. When the grease-laden solvent is introduced it is vaporized and then condensed in a jet condenser, while the grease is left as residue and is drawn off to storage tanks.

"The discharge door on the side of the reducer is then opened. The agitator is so shaped that when revolving it has a tendency to push the mass out toward the sides of the reducer, thus making it self-emptying. It requires about fifteen minutes to empty. The material as it leaves the reducer is of a brownish color, and has an odor not at all offensive, reminding one of fresh roasted coffee. It is then perfectly dry and sterile, and is usually called tankage.

"The tankage is discharged from the reducers at a uniform rate, and drops by gravity onto a belt conveyor for transportation to the tankage house. Although the material is warm, it is not hot enough to do any damage to the belt conveyors. By a series of longitudinal cross and inclined belt conveyors, the tankage is elevated to a point about 50 ft. above the ground, where it is discharged into a large revolving screen, provided with riding rings that run on revolving trunnions. The screen is made of wire cloth with 1½-in. mesh. The tailings are discharged onto a slow-speed belt conveyor. Two men are stationed alongside this conveyor. One picks out all bones and drops them in a chute that leads to a distributing conveyor, which distributes and discharges them to the storage room below. The other picks off all rags and tosses them to the storage bins. The material left on the belt, consisting of sticks, corncobs and miscellaneous rubbish that would not pass through the preliminary screen, is discharged to a chute that leads to a rubbish car. This material is deposited on a dump.

"Corn husk, which fortunately comes only two or three months in the year, is one of the most difficult materials to put through the plant, and is practically worthless as a tankage content excepting for the small amount of potash it contains. It is proposed at this plant to pick the corn husk out of the green garbage at the dock and char it in a revolving drum, thus eliminating it from the conveyors and reducers and also conserving the potash content

"The tankage that passes through the meshes of the preliminary screen is chuted to a scraper-conveyor that distributes the material to a row of four revolving screens that are duplicates of the preliminary screen, excepting that the mesh is much finer. Material that passes over the ends of these final screens is discharged onto a belt conveyor provided with a magnetic head pulley. This pulley removes all particles of iron, such as hairpins and knives and forks. The amount of iron recovered is less than 0.25% of the tankage.

"From this belt conveyor the material passes to a scraper-conveyor that moves the material to two dry-grinding pans. These consist of heavy cast-iron bowls, 9 ft. in diameter, in which the material is ground by a pair of heavy revolving cast-iron rollers whose weight is sufficient to grind anything short of steel ball bearings. The ground material is discharged onto a belt conveyor and thence to a screw conveyor that carries the material to a vertical bucket elevator. From the elevator the material chutes to a scraper conveyor which carries it back to the screens for rescreening. It will be noted that at this point there is a complete cycle, so that all material passing through the preliminary screen is either screened through the final screens or removed by the magnetic separator. Occasionally there are large pieces of brass, etc., that will neither grind nor separate. These are removed by hand from the dry pans or from one of the belt conveyors.

"The material that passes through the final screens is finished tankage, and is transferred to an 80×100-ft. storage house by a series of conveyors and elevators so arranged that it can be completely filled.

"All tankage is shipped from the plant in boats, so there is no necessity for bagging. The tankage is dropped from the storehouse floor to two parallel belt conveyors which discharge onto inclined belt conveyors leading to swivel spouts placed on the dock. The spouts finally deliver the tankage into the holds of the boats.

"A narrow-gage industrial railway connects the various departments of the plant. It is equipped with gasoline locomotives and standard contractor's dump cars. This railroad was used to good advantage during the construction of the plant and is also used for the wasting of rubbish and for fetching coal from the storage piles.

"Commercial electric power has been used throughout the plant for driving machinery, conveyors, and salt-water rotary pumps.

"Steam is used in the reducers, stills and reciprocating pumps from a 55×140-ft. boiler house containing five 610-h.p. water-tube boilers. The stack for the boilers is of concrete, 19 ft. in diameter by 203 ft. high.

"Coal for the boilers is unloaded from the barges by a clamshell bucket and placed in a hopper on the dock. The coal received is 'run-of-mine' and is fed by a double-plunger feeder into a two-roll crusher that reduces it to the proper size for the stokers. The coal hopper is placed close to a hopper for receiving garbage so that the same grab-bucket can unload either coal or garbage.

"From the crusher the coal drops to a belt conveyer that travels up and alongside the reducer building and deposits the coal on a conveyor at right angles that travels on an incline to a position over the bunkers in the boiler house. Two stationary trippers are placed in this belt, outside of the boiler

house, so that coal may be stored on the ground. The local industrial railroad carries this coal to the boiler house on a track provided for the purpose. A depressed track of the industrial railway leads under the stokers, so that ashes drop directly into dump cars.

" The absence of railroad communication necessitated the construction of large storage containers for both solvent and finished products. This is particularly true of the grease-storage tank, which is 55 ft. in diameter by 30 ft. high, and of the grease barreling house.

" In the barreling house are placed eight 10×23-ft. vertical steel tanks, into which the grease is pumped before barreling. These tanks have conical bottoms and the draw-off pipe for the finished grease is well up on the side. The grease is pumped into these tanks and allowed to settle. The heavy grease and impurities settle to the bottom while the pure and lighter grease is drawn off to the barrels for shipment to be used in the manufacture of glycerine, soap, candles, etc. The building is of concrete and brick, and is 100×100 ft. It is placed near the dock to minimize handling of the barrels. A completely equipped chemical laboratory occupies one corner of the building. Elsewhere there is a 30×120-ft. machine and repair shop."

The plant worked satisfactorily, and without any offensive odors, until 1919, when war prices caused financial difficulties for the company, and a consequent failure to maintain the works in proper operating condition. This resulted in the escape of gases and odors sufficient to cause a public nuisance. The inefficient condition was increased by the failure of the company to enlarge the works to such an extent as to keep pace with the gradual increase in the quantity of garbage, and the peak loads could not be treated properly. It has also been reported that there was difficulty in securing the requisite labor. As a result the company's affairs were placed in the hands of a receiver, and the garbage was again taken to sea and there dumped.

2. Los Angeles, Cal.—During 1914 a Cobwell type of garbage reduction plant, having a capacity of 175 tons daily, was built in Los Angeles, under a contract between the City and Mr. C. D. Crouch, by which the city receives 51 cents a ton for all garbage delivered to the plant. Figs. 119 and 120 show a general plan and a view of the works. The following description is condensed from an account * by Mr. Seward C. Simons, Assistant Engineer during the construction of the plant.

The garbage is delivered to the plant in wagons having removable steel bodies which are emptied into a garbage bin or dump by an overhead crane.

From the garbage dump the material is raked on a scraper conveyor which carries it across to the reducer building. This building contains 20 reducers, which form the central part of the system. The

* *Municipal Journal*, June 10, 1915.

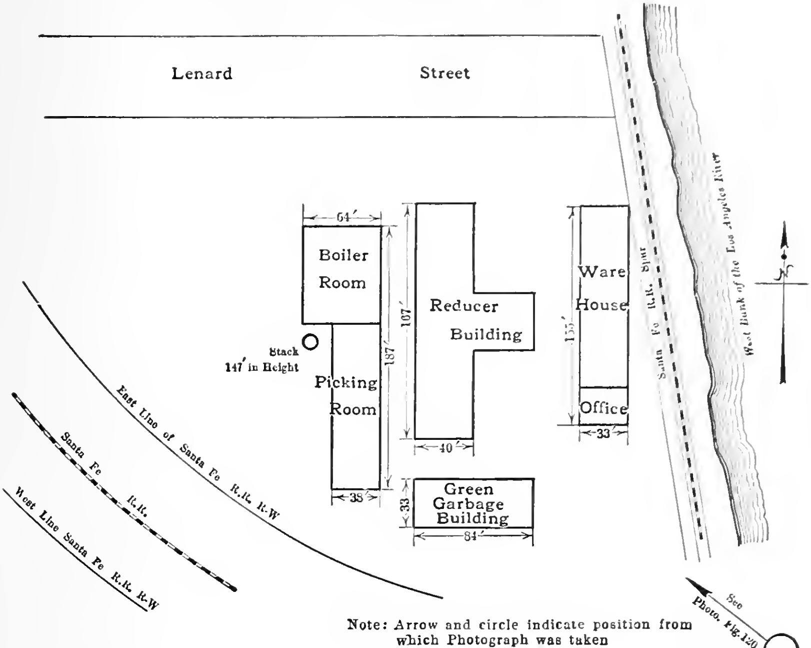


FIG. 119.—General Plan of Reduction Plant, Cobwell Process, Los Angeles, Cal.

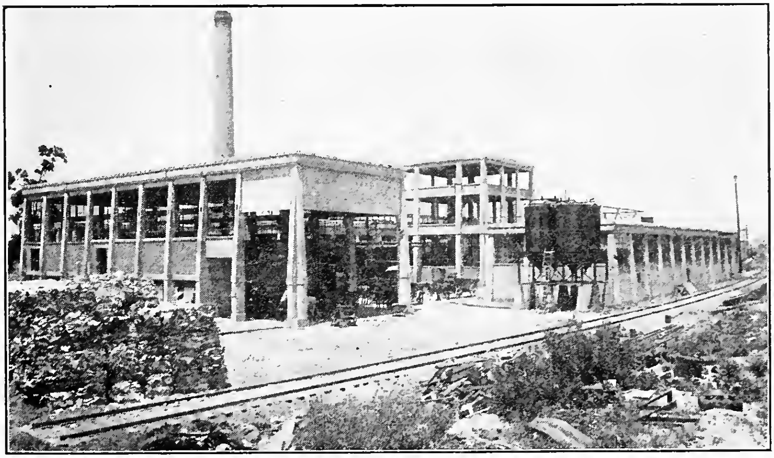


FIG. 120.—View of Reduction Plant, Los Angeles, Cal.

scraper conveyor passes along the center of this building near the roof, and feeds the garbage into the reducers through movable chutes.

This system of reduction, which is known as the Cobwell, was first developed by the C. O. Bartlett and Snow Company, the general contractor for the plant. The reducer is a steam-jacketed, cylindrical apparatus, 8 ft. in diameter and 4 ft. high. The inside is fitted with an agitating device rotated by gears placed on the upper portion of the apparatus. Each reducer holds about 3½ tons of garbage per charge. As soon as the reducer is filled, a solvent known as cobolene (a petroleum product not greatly different from naphtha) enters in sufficient quantities to cover the mass, and live steam at a pressure of 85 lb. per square inch is admitted to the jacketed walls and bottoms, after which the stirring device is started. Connected with the reducer is a large vapor pipe running to a condenser. The principle of the operation depends on the fact that water is vaporized at a lower temperature when evaporated along with a solvent having a low boiling point. As the water and solvent are evaporated together, the solvent is separated by gravity and returns to the reducer, and the water, which is perfectly clear, flows to the sewer, the operation being continued until a test shows that all the water has been removed and the solvent is running over clear.

The material is now dry except for the solvent and the grease, the latter, by this time, being entirely free and dissolved in the solvent. The solvent and grease are then drained from the reducer to a still, from which the solvent can readily be driven off and the grease recovered. When the last traces of solvent have been removed by further heat, the garbage is discharged through a door in the side of the apparatus by using the agitating device. The whole operation in the reducer requires from ten to sixteen hours.

The matter discharged from the reducer, known as tankage, falls from the door of the reducer on a scraper conveyor which carries it to a second conveyor and thence to the warehouse. At the warehouse the tankage is passed through a rotary screen, any material which is not fine enough being ground in a special rotary grinder, and the finished product, ready for sacking, is delivered by a screw conveyor.

At the works there is also an equipment for sorting rubbish and a furnace for burning the combustible portion which has no market value.

3. Cleveland, Ohio.—The present Cleveland plant is a development from experiences with a number of types of apparatus. The works are at Willow, 2 miles south of the southerly city limits and about 9 miles from the garbage loading station in the city. The first works were built by the Newbury Reduction Company in 1898.

The process consisted of cooking, followed by hydraulic pressing. The dry tankage recovered amounted to 8 or 10%, and the grease to slightly more than 2% of the original weight of garbage.

The city bought the plant in 1905, and, under the guidance of Mr. W. J. Springborn, established the Edson process. Its distinctive feature was the use of steam jackets and mechanical stirring devices in cooking and drying, but it was found to be slow and too costly. The plant, therefore, was remodeled, and is described as follows:*

"The old method of unloading the garbage from tank wagon bodies by a crane has been abandoned, and there is now provided a green garbage building where the garbage cars of special type are emptied. This building is a brick structure, 100 ft. long, 32 ft. wide, and 30 ft. high. The cars enter the building on an elevated track about 12 ft. above the floor level, and are dumped by chain hoists. A large quantity of the free water contained in the garbage is drained off through suitable openings, and at present is discharged directly into the river. This green garbage building is a short distance from the main building, to the top story of which the garbage is carried by scraper conveyor, discharging through chutes into the digesters. There are sixteen new digesters in the remodeled plant, all the old ones having been removed. The digesters are each 54 in. in diameter and 14 ft. deep, and are constructed of $\frac{5}{8}$-in. riveted steel plates, the interior being lined with 2-in. cypress lumber. Each digester is provided with a false bottom consisting of a perforated metal disk. On the side of the digester, just above the false bottom, is a door for removing the tankage, and a coil of steam piping is placed immediately below the false bottom through which the steam for cooking is applied. Steam is admitted directly to the material, for a period of six hours, at a pressure of 70 to 80 lb. After digestion is completed, steam pressure is applied at the top, and the free liquor is driven off through a connection at the bottom, and conveyed to settling tanks, where the grease rises to the top and is skimmed off. The liquor from the bottom of the settling tanks is wasted into the river.

"The tankage from the digesters is removed in specially constructed cars, from which it is discharged into a conveyor leading to the driers. The Edson driers used in connection with the old process are now used to dry the tankage partly. Three driers are provided, each of which is of such capacity as to receive two digesters full at a charge. The material is dried during a period of somewhat more than two hours, with a steam pressure in the jacket of from 70 to 80 lb., corresponding to about 320° Fahr. After discharge from the Edson driers the tankage contains about 40% of moisture.

"From the Edson driers the material is conveyed to a final drier, which is the design of Mr. E. S. Peck, former superintendent of the works. This drier is 30 ft. long and 4 ft. 6 in. in diameter, and is set at an angle slightly inclined from the horizontal, so that the material passes through it continuously by gravity. The drier has a $2\frac{1}{2}$-in. steam jacket around the outside and a 12-in. steam drum extending through its center. It is also provided with a hot blast,

* "Report on Collection and Disposal of City Waste in Ohio," Ohio State Board of Health, 1910.

the air being heated by a system of steam coils at the discharge end of the drier and drawn by a fan at the charging end. The cylindrical body of the drier is revolved on roller bearings, the power being supplied by a motor. During drying, steam is applied in the jacket and drum at 70 or 80 lb. pressure, and the hot-air blast is applied at a temperature of about 250° Fahr. By passage through this drier the moisture content of the tankage is reduced to about 5%.

"After drying, the material is conveyed to the percolator building, a short distance from the main building. It contains the percolator and two grease separators. The percolator is of a special design, also devised by Mr. Peck, and consists of a steel cylinder, 8 ft. in diameter and 15 ft. long, set horizontally, and resting on bearings on which it may be revolved. An opening is provided at the top, through which the charge of tankage is admitted. It is usual to fill the percolator two-thirds full of tankage. It is then flooded with naphtha introduced at the top, and, after standing about one-half hour, the naphtha is withdrawn and the percolator again flooded with fresh naphtha. This process is repeated until the color of the naphtha indicates that the grease has been almost completely removed. After the last flooding of naphtha is withdrawn the percolator is turned over and steam at from 10 to 15 lb. pressure is passed through the tankage to remove traces of naphtha. The charge is then dropped to the floor from the percolator. The steaming adds about 10% of moisture to the tankage, but this is not considered objectionable. The tankage is carried in a conveyor to a revolving screen and, after screening, is ready for shipment. The screen tailings are dumped near the plant.

"The naphtha containing the grease is conducted to two separating tanks. These are horizontal cylinders, 12 ft. long and 6 ft. in diameter, and have a steam coil along the bottom. The naphtha is evaporated, and the vapors are condensed and stored for use again. The grease is withdrawn and stored for shipment."

4. Columbus, Ohio.—One of the best of the garbage reduction plants was built in Columbus in 1907, and was put into operation in 1910. It has a rated capacity of 160 tons per day. The following is condensed from a description by Osborn,* who was in charge of the construction:

The reduction plant is about 4 miles south of the center of the city, on the Scioto River, and near the sewage purification works. The railroad tracks at the plant are on top of the levee which surrounds the building site, and about 10 ft. above the ground floor of the buildings. This elevation allows all material coming to the plant to be discharged from the cars by gravity.

At the plant there are four buildings, the main building, the green garbage building, a small office building, and a stable. The garbage when delivered at the plant is weighed on railway track scales and then run into the green garbage building. The body of the car is then turned on trunnions by power hoists, and the contents of the car are discharged on the floor below. The free water is drained off through a gutter extending the full length of the

* *Engineering Record*, November 19, 1910.

building and covered with perforated plates. The swill water from the gutter is drained into a catch-basin, from which it is discharged into the grease-separating tanks, after which it is evaporated. The garbage is sorted and shoveled into a 24-in. scraper conveyor which extends the full length of the green garbage building. Connecting this building with the main building is an inclined truss which carries the conveyor to the top of the main building and over the tops of the digesters, into which the garbage is discharged directly.

There are eight digesters, and they have a capacity of from 10 to 12 tons of garbage. The inside is lined with cement and tile, $1\frac{1}{2}$ in. thick.

The steam is turned on, and spreads and circulates through the mass. When cooked, the garbage is discharged through a large valve into the receiving hopper, which is connected directly to the roller press.

The vapors which arise from the mass when dropped into the receiving hopper are conducted by a vent line to a condenser, which, with the condenser for the digesters, is connected to a vapor-tight steel hot well. Any odors that are carried by the gases and not taken up in the condensers are trapped in the hot well and then passed by a vent line to the boiler furnaces.

The time required in cooking varies with the quality of the garbage, but averages about six hours with the steam at from 60 to 70 lb. gauge pressure as it enters the digester.

The presses, which are connected to the receiving hopper, are of the continuous roller type, and were designed by Edgerton especially for handling garbage. They are connected directly to the bottom of the receiving hoppers, so that the material from the digesters passes through the press before being exposed. The press is provided with upper and lower conveying aprons. The upper apron acts as the bottom of the receiving hopper, carries the material through the feeding rolls, and discharges it on the lower apron. The lower apron passes between six cast-iron rolls, arranged in pairs. The rolls are 28 in. in diameter, and are controlled by heavy steel springs so that they may be regulated to any desired pressure, depending on the quantity of material to be passed through.

The pressed material is discharged at the front of the press into a scraper conveyor which carries it to the second floor of the drying department. The pressing rolls are driven by chains, and the press is constructed so that one apron, or both, can be operated at the same time. On the feeding roll is a safety device to protect the press, should any foreign substance, too large to pass through or too hard to be crushed by the rolls, get back of the rolls. The press can be reversed, so as to remove any material, if desired, from under the rolls.

The water and grease flow back from the press through a covered conduit to the catch-basins in the grease-separating room, below the floor. The water and grease are pumped from the settling basins into a battery of tanks, where the grease is separated by gravity. There are six separating tanks. The grease rising in the first tank overflows into the second, and from the second to the third, and so on through all the tanks, with the largest quantity of grease collecting in the sixth tank, from which it is drawn off through a pipe line into one of two treating tanks.

The grease drawn off from the separating tank is heated in the treating

tanks, in order to separate the impurities, and then pumped into storage tanks for shipment. There are four grease storage tanks with a total capacity of 15,000 gal. They are piped so that the grease can be pumped into any of the tanks or be drawn off and discharged into railway tank cars for shipment.

The liquor as it comes from the presses carries more or less solids in suspension. These solids are known as muck and silt, and are drawn off by a Magma pump and discharged into a muck tank, from which they pass through a screw press into catch-basins, and the solids are placed on the conveyor leading to the drier room.

The tank-water from the storage tank goes to a triple-effect evaporator, so as to recover the 5 to 7% of solids in solution. The evaporator is capable of concentrating 1500 gal. of tank-water per hour.

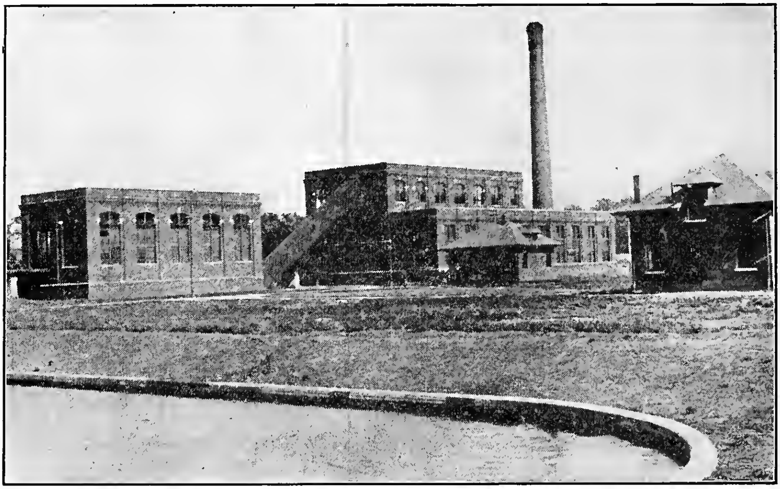


Fig. 121.—View of Reduction Plant, Columbus, Ohio.

The solids from the roller presses, after they are delivered to the drying department, are fed into a revolving cylindrical drier. The dry material is elevated to the second floor and passed through a revolving screen. The screened tankage is then placed in the vacuum or mixing driers and the concentrated syrup from the evaporator is added. The dry fibrous material acts as a filler, enables the moisture in the syrup to be driven off, and the fertilizing value to be increased. When dry the material is discharged from the drier into a spiral conveyor connected to an elevator which discharges it on the third floor, where it is stored until shipment.

The city has since constructed a percolating plant to be used in the extraction of grease from the dry tankage, as only about one-half of the available grease is recovered by the press. It consists of extractor, vaporizers, condensers, and storage tanks, and is in a special small building. A general view of the plant is shown in Fig. 121.

5. Chicago, Ill.—The plant of the Chicago Reduction Company was purchased by the City in 1913 at the reduced price of $279,689. Since then it has been very largely remodeled by the City. A brief description of the present plant,* made up chiefly from published articles by Col. H. A. Allen, the designer, follows:

Garbage is brought to the plant in specially designed boxes, by wagons and barges. The wagon bodies are lifted by cranes, and their contents are discharged into large concrete bins with hopper bottoms fitted with large swing gates on horizontal openings. From these hoppers the garbage is elevated by conveyors to the top of the drier building.

Generally, the garbage is first run through a crusher to smash cans of condemned foods and to break up other large materials for more efficient drying. The material from the crusher is then fed into driers in which its moisture content is reduced to about 10% or less. The dried material is fed into percolators where it is treated with a grease solvent. The grease-saturated solvent is then drawn off and the solvent distilled out and condensed for re-use, the grease being treated and stored for shipment. Steam is then turned into the percolator to drive off any residual solvent, after which the tankage, containing about 26% of moisture, is withdrawn and put through final driers, in which the moisture is reduced to from 6 to 8%. The tankage is then screened, milled, and finally stored for shipment.

This so-called " drier system " was selected by Col. Allen for the following reasons, as stated by him:

" My investigation convinced me that one great cause of offense at the plant of the Chicago Reduction Company was due to the use of direct-heat driers and consequent burning or carbonizing of certain greases and materials, such as hair and flesh. It would seem that certain odors thus formed are not soluble in water, therefore not readily washed or scrubbed. This scorching action not only was the cause of offense, but also, I believed, the cause of loss in the value of by-products.

" The result was the installation of the more costly direct-indirect heat driers.

" As predicted, when using the indirect-heat driers, not only has the necessity for scrubbing practically been eliminated, but the produced tankage and grease are better, with consequent increased values. The garbage is dried from 75% moisture to 10% or less in one cylinder."

In order to eliminate offensive odors, each drier is provided with a " petticoat " stack consisting of a series of concentrically placed steel cylinders, each one larger than the preceding lower one. These

* The old plant is described in *Engineering News*, Vol. 59, p. 278.

stacks promote commingling of outside fresh air with the escaping gases from the driers, thus cooling them and throwing down a certain quantity of moisture which carries with it some of the fine suspended

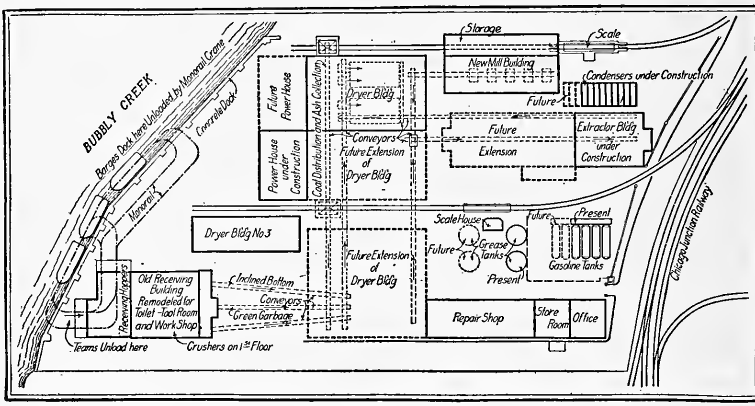


Fig. 122.—General Plan, Reduction Plant, Chicago, Ill.

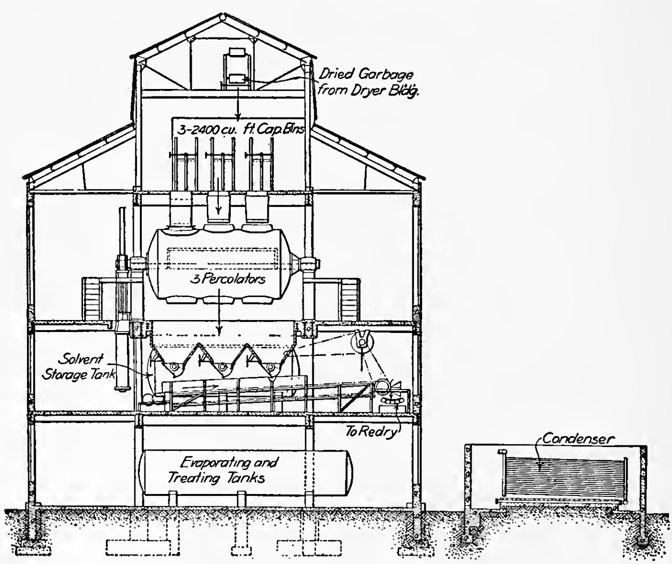


Fig. 123.—Cross-section, Chicago Reduction Plant.

matter. The fresh air also causes some dilution. The stacks, however, are provided with suitable sprays for use in emergency.

The plant is able to treat about 1200 tons of garbage per twenty-

four hours, and, during 1917, handled an average of 600 tons per twenty-four hours.

Fig. 122 is a general plan of the Chicago plant, Figs. 123 and 124 are cross-sections, and Fig. 125 is a longitudinal section.

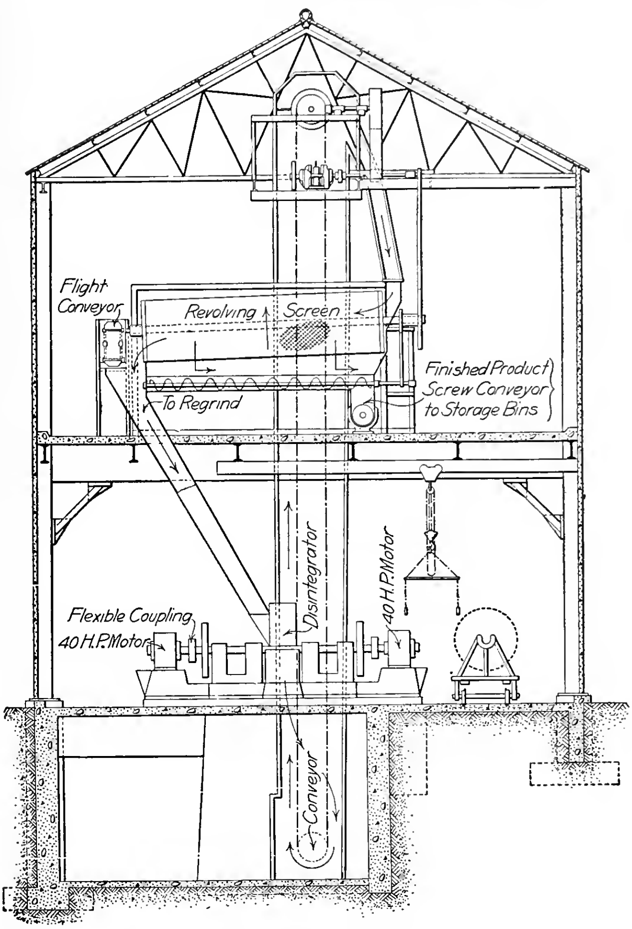


Fig. 124.—Cross-section, Chicago Reduction Plant.

6. Boston, Mass.—The first reduction plant for Boston was built in 1895, on Mt. Vernon Street in Dorchester. The Arnold process was used, from plans furnished by Edgerton. The plant went into operation in January, but was shut down on March 21st because of the nuisances created.

A second plant, using the Arnold process, was built at the "Cow Pasture" in 1898. Within a radius of 2 miles of it there was a population of from 50,000 to 75,000. It cost upwards of $300,000, but, as there were continual complaints of nuisance, it was removed in 1900 to Spectacle Island, about 3 miles out in Boston Harbor. This plant was used until 1912, when it was entirely rebuilt, because of the high cost of operation and the production of odors, which were annoying at the main land. The new plant is described briefly as follows:*

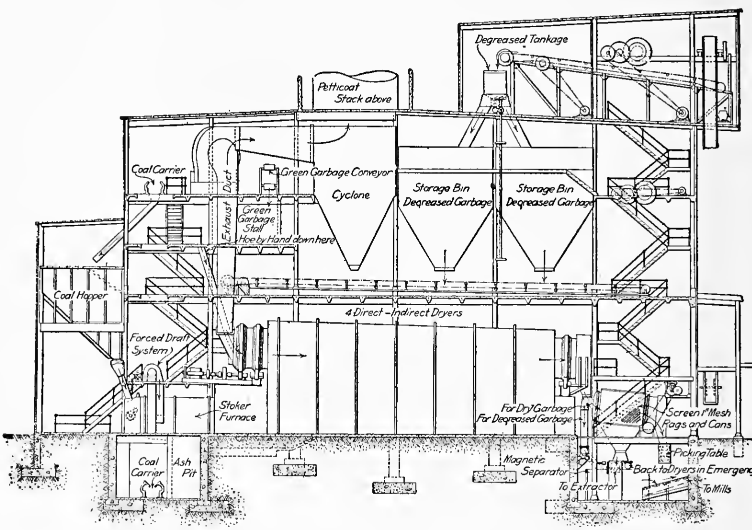


Fig. 125.—Longitudinal Section, Chicago Reduction Plant.

The plant is on the westerly side of Spectacle Island. There are four principal buildings: The main building, containing the digester house, evaporation room, drier room, power plant, and incinerator; the percolator house and two storehouses. Gasoline used in the percolation process is stored in tanks out of doors, about 100 ft. from the percolator house.

On arriving at the wharf, the garbage is transferred from the scows to the main building. The green-garbage conveying equipment consists of a 48-in. pan conveyor, running 45 ft. per minute, and a 24-in. scraper conveyor, running 50 ft. per minute. The capacity of each conveyor is 100 tons per hour. The pan conveyor receives the green garbage from the bin and carries it upward through a picking gallery

* Abstracted from *Engineering Record*, 1913, p. 512.

where foreign materials are culled out. The garbage is then delivered on the scraper conveyor, which is inclosed, and is carried by an inclined truss to the top of the digester house.

The digesters are in two rows of eight each. Each unit has a capacity of 13 tons, is 90 in. in inside diameter and 19 ft. 6 in. high. Through $1\frac{1}{2}$-in. pipe connections, live steam is admitted at a pressure of from 75 to 90 lb. per sq. in. for cooking.

In operating the digesters, the steam is turned on for an hour and then shut off for an equal period, this cycle being repeated on the average for ten hours. If the garbage is old and soft it cooks much more rapidly than when green and stiff, and the reduction of weight by evaporation slightly increases the nominal percentage of grease obtained and reported. The degree of digestion is determined by loosening the inlet door. The material when cooked has an odor resembling that of licorice. There are two receiving tanks under each row of digesters, each tank being supplied by four digesters. Directly under each receiving tank there are two presses. The green garbage has about 80% of moisture when delivered; this is reduced to about 50% by the press treatment, and by subsequent drying to 8 or 10%. Each press has a capacity of from 5 to 6 tons, the time required for pressing, including filling, being from five to six hours.

The tank-water flows into a row of settling basins, 95 ft. long and 11 ft. 6 in. wide. The weir system and the independent basin system of grease separation are in use. The basins are of concrete and are lined with timber. The tank-water flows into any one of four small receiving basins, where the first grease separation by flotation occurs. After the removal of grease, the tank-water is delivered into the settling basins. When the weir system is used, the tank-water is pumped into the first of the large settling basins, where a further separation occurs, the process being continued in the succeeding basins, with a diminishing accumulation of grease in each. Sludge can be removed from any of the basins by a centrifugal pump and re-treated in the presses.

The greater portion of the grease is separated in the receiving basins. A pump near the first large settling basin delivers the grease to a battery of three 6600-gal. treating tanks. At these tanks the grease is heated by steam coils, to separate the impurities, and is then discharged into barrels or pumped into steel storage tanks prior to shipment.

The tankage from the presses is discharged on the floor of the pressroom and passes to an 18-in. scraper conveyor which carries it to the charging floor directly above the drying equipment. The

tankage enters the driers through charging holes, and is discharged at the lower ends of the driers on an 18-in. scraper conveyor, which carries it to the upper floor of the percolator building. Here it is discharged into the percolators. The garbage contains from 4 to 6% of grease; about 3% is removed by boiling in the digesters and the remainder by the percolation process. From ten to twelve hours are required for treating each charge of tankage.

Rubbish is also taken to this plant, where the valuable portions are sorted out and the remainder is burned in a high-temperature refuse incinerator having a capacity of 40 tons per day. The incinerator furnishes heat for a 250-h.p. boiler, which supplies about 15% of the steam used at the plant.

7. Washington, D. C.—The following information, relating to the first year's operation of the municipal garbage reduction works of Washington, is taken from an article by Mr. F. C. Bamman, in *Engineering News-Record* of May 6, 1920:

The reduction works were built about twenty years ago, and have been in operation continuously. The process used is cooking by steam in sealed digesters, pressing by internal steam pressure and then in hydraulic rack presses, drying the pressed cake in a direct-heat drier, and passing the liquids thus extracted through settling and grease-skimming basins. Extraction by using solvents is not attempted, and there is no equipment for the recovery of the solids contained in the liquids from the presses.

On July 1, 1918, the District took over the complete plant of the former contractor and continued the work practically on the same lines.

The revenues for the first year exceeded the expenses, and would show a small profit, according to most methods of municipal accounting; yet, when, to the items regarded by the municipality as expenses are added those other unavoidable items which a private company recognizes as expenses, the profits are much less.

The relatively poor showing of the plant is not necessarily a reflection on the ability of the municipal officers charged with its operation. The plant had been allowed to deteriorate by the company during the closing months of the contract, and the spirit of labor unrest, high labor costs, the usual legislative "red tape" limitations, the big decrease in prices of by-products, etc., all served to bring about a condition detrimental to efficient management.

The plant is isolated; condensation of the vapors has not been necessary; the digesters are vented directly into the atmosphere; and the drier fumes undergo no treatment to relieve them of odors.

The main building contains 24 Chamberlain digesters, 8 hydraulic rack presses, unloading apparatus, skimming basins, etc. The drier house, with a single direct-heat drier, is about 100 ft. away, and the pressed cake is carried from the presses by a belt conveyor. The power plant, containing six boilers (total, 450 h.p.), is between the two buildings.

From a municipal standpoint, the plant is far from satisfactory, and, though many improvements have been made, the District officials regard it as only a temporary expedient. The changes made by the municipality include improved methods of unloading, new digesters, relocation of railway siding, etc. Others are being made or are contemplated, but these are only intended to continue operations until a permanent method of disposal is determined.

The statement of expenditures, fixed charges, revenue, profits, etc., by Mr. Bamman, differs in several respects from that of the District officials, but this is explained as due to several factors which should be considered carefully in making comparisons with data from other plants. For example: In the Washington figures, no interest on working capital has been included; insurance in any form is prohibited by law; no taxes are paid; general office expenses properly chargeable to operation are not included; no *pro rata* charge has been made for the time of the Supervisor; the salaries and considerable expenses incidental to selling by-products and keeping accounts are not included; neither are such items as postage, stationery, telegraph, and telephone, the *pro rata* share of the purchasing department chargeable to reduction, or the similar amount chargeable because of auditors' expenses; the rental charge for office space in Washington; the *pro rata* share of the salaries and office expenses of District officials superior to the Supervisor of city refuse, etc. It will be realized at once that these items would have considerable influence on the cost of operating this plant as a purely commercial enterprise.

The prices realized for grease and tankage are indicated in Tables 137 and 138. During the war, garbage grease prices rose rapidly, due to its glycerine content, which is about 10%. Grease contracts, generally, expired on December 31st, 1918, and, the armistice having been signed, and the need for glycerine explosives no longer existing, many plants were without contracts, or had to sell their products practically at the buyer's offer. In the District plant the return was reduced by nearly one-half.

Tankage contracts were affected in the same way by the release from munition purposes of nitrogen carriers. With the decrease in grease and tankage prices, there came, also, increases in the cost of labor.

TABLE 137.—Grease Contracts,
Washington Garbage Reduction Plant, July 1, 1918, to June 30, 1919

(From *Engineering News-Record*, May 6, 1920)

Contract prices effective	Price per pound, in cents	Pounds sold, net	Percentages *			Total money received, f.o.b. plant
			Moisture	Insoluble	Unsaponifiable	
July–Dec., 1918	$13\frac{5}{8}$	906,690	1.62*	0.48*	2.23*	$121,887.88
January, 1919	7.03	156,300	1.56	0.26	2.19	10,881.55
Feb.–March, 1919	5.28	452,739	....	....	....	23,706.79
April–May, 1919	5.02	397,513	....	....	....	19,678.42
June, 1919	6.55	144,342	....	....	....	9,282.80
Totals for year	....	2,057,584	....	....	....	$185,437.44

* Under each contract 3% of moisture, impurities, and unsaponifiables was allowed.

TABLE 138.—Tankage Contracts,
Washington Garbage Reduction Plant, July 1, 1918, to June 30, 1919

(From *Engineering News-Record*, May 6, 1920)

Contract prices effective	Ammonia, NH_3	Bone phosphate P_2O_5	Potash, K_2O	Tons sold	Total money received
July–December, 1918	$5.62	$0.10	$1.00	1637.82	$30,001.92 *
January, 1919	2.75	0.10	0.60	322.72	3,319.07 *
February–March, 1919	2.35	0.10	0.00	631.16	3,630.94 †
April–June, 1919	2.25	0.10	0.00	787.95	4,619.63 †
Totals for year	......	......	......	3379.65	$41,571.56

The prices given are per ton of tankage for each single per cent. of the respective items.
* F. o. b. plant.
† Less freight.

There was an increase in the production of garbage in Washington during the war period, instead of a decrease, as in most other cities. The totals for the years ending June 30th were:

1916	52,202 tons
1917	44,683 tons
1918	48,843 tons
1919	53,258 tons
1920	52,800 tons

This increase, without doubt, was due to the increased population engaged in war activities. The production in 1919 was greater than in 1918, which condition is also noted in most other cities, for, as soon as the patriotic need for food conservation ended, high prices failed to reduce the waste. In 1920 the production of garbage was 241 lb. per capita, the grease extracted was 1.76%, and the tankage was 5.8%.

From articles by Maj. F. S. Besson, in *Engineering News-Record* of December 2, 1920, and February 10, 1921, the following information is extracted: Detailed estimates by Maj. Besson indicate that the economy of establishing a farm and feeding the garbage to hogs would be doubtful. Estimates of the cost of building and operating a new reduction plant are given, also the cost of continuing the present plant, but with necessary extensions and improvements, and also betterment of the transportation facilities. A comparison shows that improving the present works is much more economical than the establishment of a new plant, the figures being:

$0.05 per ton debit with present plant,
0.72 per ton debit with new plant,
0.88 per ton credit with present plant improved.

Incidentally, it is noted that no provision is made for percolators. "They are omitted because of the determination that the value of the additional grease obtained would not compensate for the extra fuel and solvent consumption required for percolators.

"A prime essential in the disposal of the garbage of a municipality is to give satisfactory service to the citizens. Probable profits from by-products of the disposal, while commanding regard, should be of secondary consideration. Entirely satisfactory results can be obtained only when it is realized fully by the public that getting rid of the garbage of a city is a function in a class with the disposal of its sewage. If this had been realized years ago, the history of garbage disposal in the first cities of the land would have shown fewer failures and less disappointment."

Table 139 is a summary of grease and tankage analyses of Washington garbage from July, 1918, to June, 1919, inclusive.

8. Schenectady, N. Y.—A typical but smaller plant, using the Chamberlain process, and designed for the reduction of 40 tons of garbage in ten hours, was completed at Schenectady in 1914. The following brief description is condensed from the *Municipal Journal*, February 12, 1914:

The plant consists of a main building, a small receiving building, with a hopper and a condenser.

A conveyor below the hopper receives the garbage and carries it to the top floor, from which it is fed directly to any one of six digesters, in which it is cooked about eight hours by admitting steam at the bottom. When sufficiently cooked, as much of the liquor as possible is drawn off, and the material further submitted to pressure by live steam. The liquor flows to five settling tanks, where the grease (about half of that in the original garbage) is skimmed off and separated from the water, which runs to a sewer.

TABLE 139.—Grease and Tankage Analyses at Washington, D. C., for the Year July 1, 1918, to June 30, 1919, in Percentages of the Weight of Garbage

(From *Engineering News-Record*, May 6, 1920)

Month	Number of analyses	Grease				Tankage		
		Moisture	Insoluble	Unsaponifiable	Available fat	Ammonia	Bone phosphate	Potash
July	3	2.43	0.53	2.27	94.77	3.06	12.45	0.60
August	2	1.41	0.48	2.58	95.33	2.80	10.53	0.36
September	2	1.63	0.54	2.30	95.53	2.93	11.95	0.33
October	2	1.98	0.55	2.30	95.17	2.86	11.36	0.41
November	3	1.02	0.43	1.99	96.56	2.86	11.71	0.47
December	3	1.31	0.39	2.12	96.18	3.12	11.80	0.54
January	4	1.41	0.26	2.21	96.12	3.32	10.49	0.41
February	3	1.26	0.32	2.16	96.26	3.04	9.57	0.35
March	4	1.50	0.32	2.23	95.95	2.98	9.48	0.39
April	3	1.38	0.43	2.43	95.76	3.08	10.62	0.29
May	3	1.68	0.35	2.43	95.54	3.22	11.34	0.32
June	3	2.35	0.83	2.55	94.27	3.10	11.30	0.33

The solid matter left in the digesters is drawn out with hoes directly to a conveyor, which runs between the two rows of digesters, carries the solid matter toward the front of the building and upward, and discharges it into a mixer. The latter breaks up any lumps which there may be, mixes the material thoroughly, and discharges it into a direct-heat drier.

The drier consists essentially of a slowly revolving steel shell, the interior of which has a series of curved plates or fins. These are fastened to the inside of the shell, and lift the material and drop it through the heat supplied by the furnace in front. The furnace is

fed by a mechanical stoker, the heat passing through the cylinder and out at the other end through a large flue to the chimney.

The dried material is carried to the percolator. As there may be naphtha fumes in the vicinity of this, and as in drying by direct heat, although none of the garbage tankage will be charred, some of the light foreign substances may take fire, the conveyor discharges the garbage on a platform in the digester building, from which (after blazing paper, rags, etc., have been removed) it is hoed to another conveyor, parallel to and about 3 ft. from the other. The material is then carried to the top of the percolator building and discharged into a rotary percolator, where it is treated with a solvent, generally naphtha, by which practically all the remaining half of its grease content is removed. The naphtha, with the contained grease, is drawn off into a storage tank, then into a treating tank, where the naphtha is vaporized and the grease is reclaimed. The vapors are condensed, and the naphtha is again used in the percolators. It is found economical to repeat the washing in the percolators four or five times. In this operation some of the naphtha is held in suspension in the tankage, and is reclaimed by "steaming out" the percolator with live steam, and thus vaporizing the naphtha, taking it to the condenser, and into naphtha storage tanks.

The tankage which has been washed and steamed in the percolator is discharged on a conveyor which runs under the percolator to a screen. Here any large lumps, and any nails, cans, etc., are separated from the tankage. These tailings are now placed over a magnetic separator, which removes the metallic matter. The tankage is ground in a Gardner crusher, then returned to the fine material which has passed through the screen, and both are conveyed to the storage room.

H. ADVANTAGES AND DISADVANTAGES

There are advantages and disadvantages in the reduction process which are important to consider, although they do not, of course, apply equally to every locality. They are summarized below. The relation of this process to the house treatment and the collection has already been noted in Chapters II and III.

Advantages.—1. The reduction process converts the organic matter of garbage, which is putrescible, into grease and tankage, which have salable values. Osborn stated in 1914 that twenty-five reduction plants in the United States produced annually about 60,000,000 lb. of grease and 150,000 tons of tankage, having an average market value of $3,500,000.

2. Through the necessity of a thorough separation of garbage

from the other materials, it permits advantage to be taken of available dumping areas, if there are any, for disposing of ashes and other inert material at a less cost for collection and disposal.

3. If the reduction method is found to be more economical in a given case than other methods, and suitable and safe designs can be made for the entire project, it is more readily adaptable, on account of its intricate nature, to be operated for business purposes by a responsible private corporation than by the present average municipal organization in our country.

4. The process affords an economical method for disposing of dead animals.

Disadvantages.—1. The first cost is comparatively high, because expensive machinery is required. The cost of renewals and repairs is also high.

2. Odors and nuisances are produced by the process, which it is costly and difficult to suppress.

3. The necessarily distant location of the plant and the careful separation of refuse add to the cost of collection and transportation.

4. The usual impracticability of having more than one plant in a city means that the entire system would be crippled if the operation of the plant were stopped by a fire, strike, or otherwise.

5. The commercial nature of the enterprise does not render it as readily adaptable to municipal operation as to the contract system, and the best sanitary conditions are not so easily maintained.

6. Fire hazards and explosions, due to the highly inflammable naphtha used for the grease extraction, have destroyed or wrecked a number of plants. Fire-proof construction, sprinkler equipments, placing the cooking and drying apparatus at a distance from the percolators, as well as guarding against corrosion, leaks, and escaping odors, make a very careful design and operation essential.

7. An increasing conservancy of fats in American households—common in Europe for many years—will tend to cause a gradual diminution of the profits from this process.

8. Past experience has shown also a financial hazard on account of the wide fluctuations in the quantity of available grease and in the market values of grease and tankage.

I. CONTRACTS AND SPECIFICATIONS

For garbage reduction work, two types of contracts and specifications have been used. One type is for the construction of a plant when a city desires to operate it, but wishes to have it built by a contractor. Such specifications have been issued at Columbus, Schenectady, Detroit, and Akron. Another type is for both the construction

and operation of a plant by a contractor. This type of specification has been issued for New York City, Chicago, Boston, Philadelphia, Los Angeles, Rochester, and some other cities.

In both types the general articles, the form of contract, and other general provisions, are similar to those commonly in use in other municipal contract work, and should conform to special local and State requirements. We do not discuss those here, but give only a summary of the more important and pertinent items.

The specifications for construction work must define the process, capacity, and character of each part of the works sufficiently in detail to insure the purchase and erection of the desired plant, including all the machinery. Typical sections from specifications that have been issued elsewhere are indicated herein, but specifications for boilers, machinery, and other standard purchasable articles are not given. The following clauses are extracted in the main from specifications issued by Columbus, Chicago, and Schenectady. It may be found important to specify, in a given case, also, some other conditions. These may be found fully described under the headings of this chapter, and suitable clauses may be added. Some of the clauses below may be found unnecessary or inapplicable in some cases.

"**General Description.**—The machinery shall be designed and constructed for the economical and sanitary disposal of garbage and dead animals by the specific process known as reduction, and, with reasonably efficient management, the machinery shall be capable of resolving these materials into commercial grease, or oil, and tankage, preserving, as far as practicable, the valuable elements, the operation to be conducted in a manner equal to the best modern practice and with the emission of no offensive odors or gases or other obnoxious wastes, solid or liquid, except those which are inseparable from the handling of raw garbage, dead animals, or the finished products of reduction under the best and most suitable methods now used.

"The salable constituents of the raw material shall be saved and recovered in the process without material loss. The oil or grease shall be produced in a salable condition; the tankage shall be thoroughly dried and screened, and shall not contain a sufficient percentage of moisture to affect its market value.

"The reduction machinery shall comprise digesters, driers, extractors, and other equipment, with the necessary piping and appurtenances, all of approved construction and design, and shall be arranged for a continuous cycle of operations, such that, after the digesters are charged, no products shall be exposed to the atmosphere until rendered non-putrescible. As far as practicable, during all parts of the process and until the finished products are obtained, the materials handled shall be in enclosed apparatus. The gases emitted shall be discharged through the fires of the furnaces, and all tank-water shall be evaporated.

"The separation of grease from water shall be done in closed tanks by using traps and overflows.

"Except as otherwise specified, the machinery and equipment installed under this contract shall be capable of reducing in the manner specified . . . tons of garbage and dead animals in each consecutive period of . . . hours.

"**Receiver Building.**—The receiver and picker building shall be provided with receiving bins or receptacles, so that the garbage when dumped from boxes raised by hoisting, or from conveying devices, will be unexposed to general view, and so that its effluvia are subject to control by the ventilating system.

"The picker building shall contain four picking or sorting belts, preferably of the pan type. Provision shall be made for properly cleaning the belts on return movement and reverse sides.

"Exhaust ventilating hoods shall be provided under picker belts at proper intervals, and fresh-air supply ventilators properly arranged, as far as practicable, to decrease any offensive odors of the delivered garbage.

"Each sorting belt shall discharge into the hopper of a disintegrator or crusher of approved make. Each crusher shall be supported on a substantial foundation and discharge into one or two main pan conveyors which carry the pulp into the primary drier building, or directly deliver it into hoppers above the driers. These conveyors shall be enclosed in sheet-iron conduits, to prevent the escape of effluvia to the atmosphere.

"There shall be provided, between the discharge of each sorting belt and the disintegrator or crusher, a shaking table to facilitate the separation of heavy materials, including glass, and for general convenience in a final sorting. The shaking table shall be provided with a magnetic separator or shall discharge upon a revolving magnetic separator.

"The material after leaving the disintegrators shall be fed into suitable compressing devices so that a considerable portion of the moisture may be squeezed or pressed out therefrom before the material is fed to the conveyors leading to the feed hoppers of the primary driers in the main drier building.

"The walls and floors of the picker building shall be of concrete and steel construction, and protected with a water-proof covering having smooth surfaces.

"The window area of the picker or sorting room shall be large, and provided with wire glass. The design shall be such as to prevent, as far as practicable, any effluvia, which are thrown off by the material when passing through the building, from escaping to the air.

"Provision shall be made in this receiver or picker building for heating the boxes containing frozen garbage, so as to allow of the dumping of their contents.

"Proper chutes shall be provided for delivering the products of sorting to proper bins.

"Provision shall be made for properly delivering carcasses to any rendering tanks or vats. The arrangement shall be such as to prevent as far as possible unsightly appearances, without interfering with convenient and economical operation.

"It is preferred that large ozone generators be installed at suitable points for ameliorating, when required, the garbage odors in the receiver and picker building.

"Proper drains shall be provided for taking care of all water freed from the garbage by action of the pulverizers and compressors, and all drippings from bins and other apparatus.

"Necessary 60-cycle, 3-phase, 220-volt, slip-ring motors shall be provided for operating pulverizer belts and conveyors or other devices required to deliver the fresh garbage into the direct-heat driers.

"Provision shall be made for properly sterilizing the garbage boxes after they have been emptied in the receiver building.

"Attention shall be given to the proper arrangement of devices for unloading, dumping, sterilizing, storing, and reloading garbage tanks or boxes, with reference to dispatch, convenience and economy of handling.

"**Apparatus.**—The receivers, commonly called digesters, shall be of sufficient size and number to handle the specified quantity of garbage and dead animals.

"The receiving hoppers shall be constructed so that the material from the digesters can be delivered to them and then to the presses without general exposure to the atmosphere.

"The presses shall be of sufficient size and number to handle the required quantity of material. The whole press shall be enclosed in a vapor-tight housing, so that the material shall not be exposed to the atmosphere while being pressed.

"The grease-separating tanks shall be arranged and constructed so that the grease can be freely separated from the liquor or tank-water, and the sediment or solids settling to the bottom can be readily drawn off or pumped to other places for pressing or disposal. All tanks shall be fitted with the necessary appurtenances to make the work complete.

"A triple-effect evaporator shall be installed, including pumps, condensers, piping, gauges, and all necessary appurtenances to make the same complete. The evaporator shall be capable of evaporating . . . . . gallons of tank-water per hour, and shall be constructed so as to resist the action of the acids found in the tank-water.

"A complete drying installation shall be made for handling the tankage as it comes from the presses, also for handling the concentrated syrup as it comes from the evaporator. The tankage from the presses should not contain more than 45% of moisture. The concentrated syrup from the evaporator should have a density of 22° Baumé, which represents a solution containing approximately 50% of solids. All vapors from the driers shall be condensed and all insoluble gases shall be passed through the furnaces.

"Two (or more) grease-storage tanks shall be furnished of suitable size and number for the storage of . . . . . gallons of grease and oil. They shall be provided with heating coils, and piped for filling and discharging.

"Suitable pumps, pressure tanks, and appurtenances shall be installed for the handling of grease, tank-water, and other liquids. Pumps for handling liquors and grease shall be in duplicate where necessary, to insure the continuous operation of the plant.

"A suitable grinder shall be provided through which the tankage may pass after being removed from the digesters and before it enters the drier.

"A wire screen having six meshes to the inch, and capable of screening the percolated tankage, shall be furnished and arranged so that the tailings will pass over a magnetic separator for the purpose of removing any remaining metal before such tailings go to the grinder. The grinder shall be capable of grinding all the tailings passing from the screen, and deliver the ground material back to the screen for re-screening.

"Conveyors shall be installed as follows:

"1. For removing the digested garbage from the digesters to the grinder and from the grinder to the drier, if such be necessary;
"2. From the discharge end of the drier to a storage room;
"3. From the storage room to the percolator;
"4. From the percolator to the screen;
"5. From the screen to the storage room for finished tankage;
"6. From the storage room to railroad cars for shipment.

"If required, an elevator shall be installed for delivering the tankage from the grinder back to the screen.

"**Grease Extractor Plant.**—There shall be furnished and installed a completely equipped grease extractor plant of modern and approved design. The various parts thereof shall be substantial in construction, and designed for safety and convenience in operation.

"The building shall be isolated from the other buildings and be of fireproof construction. It is preferable that the side-walls and floors be made of reinforced concrete and the end-walls of steel and wire-glass construction.

"All necessary devices of value for preventing fire and eliminating dangers of explosion shall be furnished and installed. All valves shall be of bronze or shall be bronze-fitted. All steam piping shall be carefully covered. All oil piping shall be extra heavy, and provided with special joints suitable to conditions attendant on handling oil.

"Attention shall be given to the arrangement of instruments, valves, and fittings as regards safety and convenience of operation.

"**Scrubbers.**—There shall be furnished and installed either two scrubbers or a duplex (or twin) scrubber of approved size and construction, complete with all necessary baffles, spray piping, and sprays, for properly scrubbing the gases and vapors drawn off from the dust chambers of the various driers, and other gases required to be treated for the purpose of practically eliminating all disagreeable and harmful odors.

"Each scrubber shall be of sufficient capacity to handle all the gases and vapors of the entire plant when working at the rated capacity. All spraying devices and piping of the scrubber shall be of brass or bronze, as approved by the city. Necessary ducts and drains shall be provided to carry off solid and liquid matters thrown down by the action of the scrubber sprays, and to deliver them to proper collecting tanks and basins.

"Provision shall be made for connecting the outlets of the scrubber with the air supply or ventilating duct serving the boilers. There shall be provided necessary gate-valves to shut off these connections to the boiler air-supply system.

" Necessary ducts shall be provided to lead the gases and vapors leaving the scrubbers to purifying furnaces. Necessary gates shall be provided to enable the inlet and outlet of each scrubber to be shut off from the rest of the system.

" **Gasoline Storage Tanks.**—There shall be provided .... gasoline storage tanks constructed in accordance with the ordinances of the City of ...., of substantial design, each provided with the necessary tell-tale valves and fittings. Each tank shall be not less than .... ft. in diameter and .... ft. high. The tanks shall be provided with substantial and properly constructed foundations, and all proper drains, pipe connections, and valves.

" **Air Heater.**—There shall be supplied a duplicate air-heater system for the utilization of the heat in the gases from the furnaces to pre-heat the air used in the driers.

" The air-heating system shall be provided with necessary high-efficiency, multivane, direct-connected, electrically driven fans, with all necessary ducts and valves. The entire construction shall be substantial, and designed for efficiency of operation and durability.

" **Dust Chambers.**—Dust chambers of approved size and construction, made of reinforced concrete, properly coated inside with water-proof covering of approved make, shall be furnished.

" Suitable stuffing-boxes shall be provided in the walls of the dust chambers to prevent the leakage of gas and vapors from them or the infiltration of air.

" Necessary drains shall be provided for carrying off any effluents that may be thrown down in the dust chambers.

" All bearings and pins on conveyors used in the dust chambers shall be of materials non-corrodible by gases and vapors encountered in the dust chambers.

" **Ventilation.**—There shall be established an efficient system of ventilators and pipes to assist in removing objectionable air from the building. An air compressor, tank, and hose shall be provided for air washing all interior surfaces.

" **Main Driers.**—The primary drying shall be done by direct-heat, revolving-type driers, the furnaces of which shall be equipped with an approved type of mechanical stoker.

" The type of stoker and construction of furnace shall be such as to permit of convenient feeding and efficient combustion of the coal used as fuel.

" Suitable automatic temperature regulating devices shall be installed, so as to maintain as far as practicable a constant maximum initial temperature in the driers.

" The furnaces of the driers shall further be designed so that they can be readily equipped with oil-burning apparatus, if found desirable to use oil as fuel instead of coal.

" Ample space shall be allowed in the furnaces for permitting the combustion flames to burn out completely before the gases enter a medium of which the temperature is below that required for the combustion of carbon. The furnaces shall be lined with fire-brick of recognized high standard, as approved by the city.

"**Recording Instruments.**—There shall be supplied the following instruments, of high quality and of types approved by the city:

"One indicating and one recording pyrometer for the furnace of each drier and each purifying furnace.

"One recording and one chemical thermometer at the discharge end of each drier.

"One recording and one chemical thermometer at each inlet and each outlet of scrubbers and air heaters on the pure-air side, and on outlets of the hot-gas sides of air heaters.

"One indicating and one recording draft gauge for each of the main stacks.

"One indicating manometer, or equivalent pressure gauge, for each main air duct, dust chamber, scrubber, air heater, and purifying furnace.

"All necessary thermometer wells shall be provided and properly placed.

"All instruments shall be substantial, neatly mounted, and properly protected against the possibility of injury.

"**Storage Building.**—A storage building shall be provided, with proper bins, and hoppers with all necessary chutes for the convenient loading of cars, and with a suitable number of bagging and weighing machines. The equipment shall be of substantial and modern construction."

Contracts for the disposal of garbage by reduction, which involve the operation of the works by the contractor, extend for various periods, and have ranged from one year (at Philadelphia) to ten years (at Boston). Ordinarily, a price bid for the disposal is paid to the contractor by the City, although, during the past few years, a reverse payment has been made in a number of cities, particularly under war conditions. Frequently, the contract includes both the collection and disposal. Advertisements, specifications, and contracts must be prepared to meet each local condition. Special clauses from a number of published specifications are given below:

"**Work to be Done.**—The work to be done under these specifications consists in the collection and removal of all accumulations of garbage and dead animals in the City of ...., for a period of .... years, to some locality or localities outside of the corporate limits of said City, except as hereinafter specified; and said garbage shall be disposed of in such a way as to be inoffensive to the owners, residents, or occupants of premises near the place of disposal, and in such a manner as to create no nuisance either at such place, on the way thither, or at any other place.

"**Garbage.**—By the term 'garbage,' used herein, is meant every kind of refuse that attends the preparation, use, cooking, dealing in or storing, of meat, fish, fowl, food, fruits, or vegetables, including every kind of condemned foods found within the City's limits, and all such material as may be from time to time by ordinances declared to be garbage, but not including street sweepings, manure, ashes, or miscellaneous rubbish.

"**Character of Garbage.**—The garbage collected and delivered by the City

to the Contractor or his authorized agents at the garbage reduction plant herein referred to will be at least 90% pure garbage by weight.

"The City does not represent itself to be the owner of the refuse, and it is understood that any independent disposal of refuse by the producers thereof shall neither make the City liable to the Contractor, nor shall the same be held to justify his default in fulfilling any of his requirements of the contract.

"The Contractor is to submit with his proposal detailed plans and specificationsshowing the proposed layout of the plant and the type and arrangement of the appliances he proposes to use, together with all other information necessary to a full and complete understanding of his bid. Plans and specifications submitted by unsuccessful bidders will be returned.

"**Probation Period.**—The garbage-reduction plant, after complete erection, shall be put into the actual service of handling and reducing all the garbage delivered by the City, and be run under probation for a period of one hundred and twenty calendar days.

"If, during the probation period, the garbage reduction plant shall have been found capable of working in a substantial, continuous, and good operative manner, in full compliance with the requirements of this contract, then the City will so acknowledge, in writing, to the Contractor, and the date of the end of the probation period shall be the beginning of the .... -year term of the disposal of the garbage.

"Should the garbage reduction plant not fulfill the requirements of this contract successfully during the probation period, then the City will so notify the Contractor in writing of its failure.

"**Failure.**—If the garbage reduction plant or any part thereof shall fail, within the probation period herein stated, to comply properly with the terms and conditions of this contract, developing any objectionable or inherent defects in the construction materials used, or defects in the design, the manner of fabrication or construction thereof, or shall fail to operate in an inodorous and sanitary manner, then the Commissioner of Public Works may declare the contract forfeited.

"**Running Condition.**—The garbage reduction plant when completely erected shall have a capacity for receiving, reducing, or disposing of .... tons of garbage per twenty-four hours.

"The machinery, auxiliaries, appurtenances, and accessories of the garbage-reduction plant herein specified, when completely erected, shall operate without undue noise, jar, heating or wearing of pins, journals, boxes, bearings, slides, or guides.

"The garbage reduction plant throughout shall at all times be kept in a first-class state of repair and in good operative condition. When completely erected, it shall be readily capable of being operated in such a manner that no offensive odors are emitted therefrom.

"All effluents discharged from the plant into any sewer shall be non-odorous, and reasonably clear.

"The time and manner of operating the plant herein specified, when completely erected, shall be in strict compliance with sanitary regulations and ordinances of the City now in force or which hereafter may be adopted.

When completely erected, it shall be operated in a manner satisfactory to the Commissioner of Public Works and the Commissioner of Health.

"**Accounting.**—During the period of this contract, the Contractor shall, at all times, keep at his office within the City, a complete set of records, books, accounts, contracts, and original vouchers of receipts and expenditures, showing in detail all the investments, disbursements, expenses, receipts, and earnings of the Contractor under said contract. Such books, accounts, records, or vouchers, relating to the business done under said contract, shall be of such character and shall be kept in such manner and form as may be required by the Comptroller of the City.

"The Contractor shall submit to the City annually, at such times and in such detail and form as may be prescribed by the Comptroller, a report of the business done under this contract for the preceding year, which report shall be sworn to by the Contractor in a legal manner.

"The City of ...., by its Comptroller or any certified accountant designated by the Comptroller in writing, shall have, and may exercise, the right, at any time or times during business hours, to make a complete examination at the office of the Contractor of all said records, books, accounts, contracts, and vouchers, for the purpose of verifying any or all of the reports herein provided for, or for any other purpose whatsoever is connection with the terms of this contract and the business done under this contract, and may audit the same at or about the end of each period of one year or at about the end of the fiscal year while such contract is in force.

"**Right to Purchase.**—The City shall have the right to purchase the complete disposal plant and all licenses and rights which may be required to operate the same after the expiration of the contract. The City shall give the Contractor at least six months' prior written notice of its intention to purchase it, and if the purchase price cannot be agreed upon, such price shall be determined by arbitration, and thereupon the purchase price will be paid and such licenses and rights transferred to the City."

The time during which contracts for construction and operation should extend is important. They are frequently for such short terms that contractors have reduced the construction costs to a minimum. Sanitary features are thus frequently neglected, and the works are operated on a merely money-making basis, cleanliness taking second place. *Engineering News* commented editorially on this condition on October 7, 1913, closing as follows:

"Either longer contract terms or out-and-out municipal ownership should be adopted, and in either case the complicated technical problems involved should be entrusted to competent engineers."

J. SUMMARY AND CONCLUSIONS

Reduction processes originated some forty years ago, and have been used chiefly in the United States. They involve a separation

of the garbage into grease, tankage, waste liquids, gases, and tailings. This is accomplished by mechanical and chemical processes. By the former the cellular structure of the garbage is broken up sufficiently to separate the organic liquids from the solid matter and allow them to be removed. In the chemical processes the grease is extracted by solvents and by cooking. The grease is separated from the water by gravitation, and prepared for the market. The water is sewage, and is turned into a sewer. The solid matter embodies the tankage and the tailings. Tankage is a brown solid residue consisting almost wholly of organic matter, and has been used as a filler for strong fertilizers or as fuel at the works. When used as a fertilizer, it requires some mechanical preparation, chiefly screening. The tailings are the solid residue from prepared tankage, and are either incinerated or, if they consist substantially of mineral matter, may be dumped. The waste liquids are treated as ordinary sewage. The gases and vapors generated are the most difficult to suppress, and have been the principal cause of objection. They arise chiefly from the digesters and driers. Care must be taken to prevent leaks and exposures, and several processes for scrubbing, washing, and burning have been developed.

The proper location of a plant depends on the equation between the cost of delivery to a satisfactory distance and the cost of suppressing all objectionable odors. A lessening of the latter cost would require an increase of the former.

The products secured are: A low-grade grease and tankage, which is a base or filler for high-grade fertilizers, both materials generally having a ready sale. The salable value has generally been sufficient to pay the expenses and yield a profit. The profit, however, is reduced with a shrinkage in the quantity and value of the grease, and by the necessity of greater expense for operating the works.

About half of the reduction works built in America have been abandoned, because of the offensive gases and vapors generated, and the dangers of fire and explosion. Under proper safeguards, however, and with sufficient expenditure, such objectionable conditions can be overcome.

The greater conservancy and waste prevention in the older European countries, and which we may be gradually approaching, indicate rather a lessening than an increase in our profits from grease extraction, unless improved or new methods reduce the cost.

Reduction plants have usually been operated by private companies under contract. In a few cities, as Cleveland and Columbus, the municipalities have undertaken to own and operate the works and dispose of the products in the market.

CHAPTER XII

ESTIMATING COSTS OF FINAL DISPOSAL

In the selection of sanitary methods of refuse disposal, the cost of building and operating the works is a most important factor. As already pointed out, the cost problem in each locality, however, should be studied as a whole, covering and including the house preparation, the collection, and the disposal.

The data in this chapter are taken from the best available published experience, and do not represent an actual cost analysis in each case. The figures have been checked carefully, in the light of the authors' general knowledge of the local conditions. However, for all special problems, the original source of our information, noted in each case, should be referred to before figures are adopted for other cases. The chief object of the present chapter is to give information to aid in the selection of the best method of disposal.

A large number of factors will influence the costs of municipal refuse disposal, both of construction and operation. Some of these, such as political influence and labor union control, are outside of the engineer's province, and cannot be included in a summary of cost data. Local standards for work and wages also affect both the cost and the quality, as well as the quantity, of work done per man per unit of time. Varying standards of sanitation among the inhabitants also have their bearing.

The offensive character of odors produced at reduction plants requires either a greater expense for their suppression at the works, or a removal of the plant to a greater distance, increasing the cost of delivery but reducing the cost of the plant.

The character of the gases and smoke coming from the chimneys of incinerators depends largely on the composition of the garbage or refuse burned, the practicable temperature obtainable, the quantity of fuel naturally available or artificially added and the efficiency of the operating force. A lower cost for fuel to be supplied may result from the tolerance of a community in allowing some odorous gases to escape from the chimney top.

The correctness of the design, of course, will affect directly both the cost and the efficiency of operation. The first cost may also be influenced greatly by the desired character of the buildings and their surroundings and the special requirements of each site.

In many instances the local situation will explain differences in the net costs reported by different cities. Some additional data that may otherwise be useful have been included in the chapters dealing with each method. A comparative study of the cost of several methods should be made, having all these and perhaps other general conditions in mind.

A. DIVISION OF EXPENSES

A proper estimation of the costs of refuse disposal, for the purpose of comparison, embodies: First, the investment for construction, etc., and secondly, the annual cost of operation. The latter should include, in addition to the purely operating costs and repairs, also the interest on the investment, a depreciation charge, but generally not a sinking fund charge. The construction cost should include engineering and legal expenses to cover the necessary preliminary and final investigations, the preparation of plans and specifications, the supervision and inspection of construction, and the expense of tests. The elements are summarized as follows:

Investment Cost

Engineering,	Land,
Legal,	Construction.

Annual Cost

(*a*) *Fixed Charges:*	(*b*) *Operation:*
Interest,	Supervision,
Depreciation,	Labor,
Sinking fund.	Repairs,
	Supplies,
	Fuel and power,
	Miscellaneous.

Generally, the cost data herein have been arranged under these items, but the local reports have been followed as nearly as practicable.

For comparative purposes, operating costs are best compiled on a basis of the work done per man per hour in each type of plant. In a

number of instances, therefore, we have included the labor schedule required for operation.

B. ENGINEERING AND LEGAL

Many of the comparative failures of refuse disposal works are due, in a measure, to improper design and construction, or to the selection of a method of collection and disposal not entirely suited to local conditions, or to laws and ordinances which have sometimes actually prevented the best solutions. These failures can be largely obviated by thorough preliminary studies, by an early adjustment of the legal and financial matters, and by experienced supervision over the design, construction, and operation. Some costs of general preliminaries and engineering work are shown in Table 140. These costs are not excessive, when considering the value of securing a longer life for the plant, fewer changes and repairs, and a better and cheaper operation.

TABLE 140.—PRELIMINARY ENGINEERING EXPENSE FOR INVESTIGATIONS AND REPORTS ON REFUSE DISPOSAL WORKS

(Approximate figures)

City	Year	Cost	Work done
Chicago, Ill.	1914	$5000	Investigation and report
Milwaukee, Wis. . .	1909	3000	Investigation and report
" "	1910–11	7000	Plans, specifications, and supervision of construction
San Francisco, Cal.	1910	6000	Investigation, report, and specifications
Albany, N. Y.	1913	2500	Investigation and report
Trenton, N. J.	1913	2000	Investigation, studies, report, and estimates of cost
Dayton, Ohio	1914	2200	Investigation, studies, report, and estimates of cost
Toronto, Ont.	1911–12	3000	Investigation, studies, report, estimates of cost, and general specifications for incinerators
Danville, Ill.	1916	650	Investigation and report
Louisville, Ky.	1917	1200	Preliminary report

The legal expenses should cover those which are required to frame the necessary laws and to have them adopted, so that the proposed work, after approval by the respective authorities, can be properly built and operated. They may include also the preliminaries for securing land, rights of way, and other property, and framing local

ordinances and regulations, concerning chiefly house treatment and the collection of refuse, and also to protect the inhabitants from nuisances and damages that might otherwise result from the careless operation of disposal works.

C. CONSTRUCTION

1. Garbage Furnaces.—As garbage furnaces are designed to burn garbage or other comparatively incombustible refuse, by using an auxiliary fuel, such as coal, gas, or oil, no boiler plant for heat utilization is ordinarily included. A summary of the construction costs of a number of plants of this type is given in Table 141.

2. Refuse Incinerators.—Plants of this type burn mixed refuse without an additional fuel. They usually include a boiler plant for utilizing the heat produced by the incinerator. A summary of the costs of construction is given in Table 142. The first cost of plants fitted with mechanical apparatus for charging and clinkering is more than that for hand-charged plants, but the operating charges are less. The itemized costs of a number of incinerators follow:

Westmount, Que.—This incinerator was built in 1906 in conjunction with a municipal electric lighting plant which uses all the steam produced. The buildings are of brick. The rated capacity of the plant is 50 tons of mixed refuse per twenty-four hours. The cost of the chimney is not included, as it is charged to the electric light plant.

Cost of Westmount Incinerator

Item	Total cost, 1906	Cost per ton of rated capacity
Buildings	$15,526.24	$310.52
Plant and machinery	18,919.56	378.40
Groundwork, roads, approaches, sidings, etc.	3,906.93	78.12
Preliminary expense, insurance, engineering, sundries	3,088.10	61.76
Totals	$41,440.83	$828.80

In 1910 a Heenan incinerator was added, doubling the capacity.

West New Brighton, N. Y.—This plant was erected in 1908. It has a Heenan incinerator, of the back-feed, hand-fired type, with a rated capacity of 60 tons per twenty-four hours. The buildings are of concrete, and exceptionally well built. The chimney is of reinforced concrete. Pile foundations and a concrete runway were required.

TABLE 141.—SUMMARY OF COSTS OF CONSTRUCTION OF GARBAGE FURNACES

Plant	Date of erection	Rated capacity, in tons per 24 hours	Character of construction	Material burned	Cost	
					Total	Per ton of rated capacity
Milwaukee, Wis.	1901	150	Brick building and chimney	Garbage	$92,000.00	$612.00
Oak Park, Ill.	1905	45	Brick building and chimney	Garbage	11,000.00	245.00
Fort Douglas, Utah	1906	20	Steel chimney; corrugated iron building	6 parts manure 1 part garbage	4,500.00	225.00
Terre Haute, Ind.	1907	40	....	Garbage and night-soil	25,000.00	625.00
Muskogee, Okla.	1911	70	....	Garbage	23,000.00	329.00
Oak Forest, Ill.	1912	24	Brick building	Garbage	12,400.00	517.00
Racine, Wis.	1913	100	Brick building and chimney	Garbage	22,500.00	225.00
Pasadena, Cal.	1913	30	Concrete building and chimney	Garbage and rubbish	51,241.00	1708.00
Minneapolis, Minn.	1901	65	....	Garbage	65,000.00	1000.00
Scranton, Pa.	1908	20*	....	Garbage	16,500.00	825.00
Spokane, Wash.	1908	30*	....	Garbage	40,000.00	1330.00
Easton, Pa.	1910	35	....	Garbage and rubbish	23,904.00†	680.00†
Chicago Heights, Ill.	1910	20	....	Garbage	2,400.00	120.00

* Capacity in tons per 24 hours computed from capacity in cubic yards per 24 hours.

† Includes land, stables, and road.

TABLE 142.—SUMMARY OF CONSTRUCTION COSTS OF REFUSE INCINERATORS

Plant	Date of erection	Rated capacity, in tons per 24 hours	Type of construction	Cost		Remarks
				Total	Per ton of rated capacity	
Hand-firing:						
Westmount, Que........	1906	50	Brick building	$41,440.83	$ 829	Not including land
Seattle, Wash...........	1908	60	Sheet-iron bldg.; concrete chimney; timber runway	36,134.50	602	
West New Brighton, N. Y.	1908	60	Concrete bldg. and chimney of very substantial construction	84,379.17	1406	
Vancouver, B. C.........	1909	50	Brick building	41,193.00	824	Includes land at $5000.00
Milwaukee, Wis..........	1910	300	Brick building and chimney	212,006.63	707	
Montgomery, Ala........	1912	60	Brick building and chimney	52,000.00	867	
Halifax, N. S...........	1912	50	Concrete building and runway; brick chimney	45,000.00	900	
Berkeley, Cal...........	1913	50	Concrete bldg. and chimney	70,000.00	1400	
Havana, Cuba..........	1914	500	Brick building and chimney	286,800.00	574	Incomplete
Mechanical Firing:						
Clifton, N. Y...........	1913	90	Brick building and chimney	132,507.00	1472	Special charging equipment
Savannah, Ga...........	1914	130	Brick building and chimney	124,665.00	959	
Paterson, N. J..........	1914	60	Brick building and chimney	80,000.00	1333	Includes building, chimney, and foundations; chimney and bldg. designed for 120 tons capacity
San Francisco, Cal......	1914	120	Reinforced concrete buildings and chimney	118,166.00	985	
Atlanta, Ga.............	1914	250	Brick building and chimney	274,750.00	1100	

Cost of West New Brighton Incinerator

Item	Cost, 1908	Cost per ton of rated capacity
Building, chimney, and runway	$37,233.85	$620.56
Furnace, boiler, fan engine, etc	23,995.00	399.92
Engine, generator, machinery (approx.)	5,000.00	83.33
Steam piping, heating	263.95	4.40
Platform scales	230.00	3.83
Land	5,070.25	84.50
Retaining wall	2,266.62	37.78
Sidewalk, approaches, etc	903.00	15.05
Engineer's house	9,416.50	156.94
Totals	$84,379.17	$1406.31

Milwaukee, Wis.—The Milwaukee plant was built in 1910. It has a Heenan incinerator of the top-feed and hand-fired type. The rated capacity is 300 tons per twenty-four hours. The building and chimney are of brick, and are on pile foundations. The prices included

Cost of Milwaukee Incinerator

Item	Cost, 1910	Cost per ton of rated capacity
Earth excavation	$1,385.48	$ 4.62
Piling	8.112,71	27.04
Concrete	7,824.22	26.08
Steel in concrete	761.15	2.54
Chimney	4,577.00	15.26
Building	20,102.00	67.07
Hoppers and parts of plant subject to wear	15,960.00	53.20
Furnaces	89,961.90	299.87
Boilers and settings	27,500.00	91.67
Piping, etc	5,000.00	16.67
Forced-draft machinery	5,000.00	16.67
Charging devices	5,000.00	16.67
Cranes, generators, compound engines	9,503.00	31.67
Clinker cars, instruments, tools, etc	4,500.00	15.00
Engineers, fees, etc	6,819.17	22.73
Totals	$212,006.63	$706.76

only a small margin of profit. The surplus steam is used to generate electricity with which to pump water from Lake Michigan to flush the Milwaukee River.

Savannah, Ga.—This incinerator was built in 1914. Its equipment comprises two Heenan top-feed, mechanically-charged furnaces, two Wickes boilers, engine and generator for supplying power to operate the plant, forced-draft machinery, and crane and grab-bucket for handling the refuse. The rated capacity of the plant is 130 tons per twenty-four hours. The building is of brick, and is well constructed. The chimney is 150 ft. high, 6½ ft. in diameter, and is built of radial brick.

The surplus steam is delivered to the adjoining water-works pumping station, and helps to operate the pumping engines.

The cost of the plant was as follows:

Cost of Savannah Incinerator

Iten.	Cost, 1914	Cost per ton of rated capacity
Excavation, foundations, etc.	$2,366.90	$18.21
Paving approaches to plant	623.98	4.80
Clinker walk	234.72	1.81
Pipe, and water softener	785.00	6.04
Testing material	307.14	2.36
Incidentals	347.53	2.67
Building and equipment	120,000.00	923.08
Totals	$124,665.27	$958.97

Seattle, Wash.—The Seattle refuse destructor was built in 1908. It had a rated capacity of 60 tons per twenty-four hours. The equipment consisted of a Meldrum furnace, hand-fired, and a continuous grate, steam-jet blowers, a regenerator for heating the air supply, and a 220-h.p. Babcock and Wilcox water-tube boiler.

The building for which the costs are given was first built with a timber frame and corrugated-iron roof and sides. It was afterward replaced by a building of concrete made from clinker produced by the refuse incinerator.

The steam generated was used for operating the plant. This plant has been abandoned, as it was found cheaper—and at present is considered unobjectionable—to dump the refuse on land.

The costs of construction were as follows:

COST OF SEATTLE INCINERATOR

Item	Cost, 1908	Cost per ton of rated capacity
Building	$3,015.74	$50.26
Inclined roadway	2,791.61	46.53
Chimney	3,326.23	55.44
Boiler and setting	6,065.52	101.09
Furnace, foundation, and fill	20,935.40	348.92
Totals	$36,134.50	$602.24

Toronto, Ont.—The incinerator was built in 1912. It is of the "Sterling top-feed" type (see Chapter X., F. 15). The capacity is 180 tons per twenty-four hours, with three furnaces in operation. The cost of construction is given as follows:

COST OF TORONTO INCINERATOR

Item		Total cost	Cost per ton of rated capacity
Property		$41,100.00	$ 228.33
Buildings:			
Mason work	$84,500.00		
Gangways	685.00		
Wiring	3,100.00		
Hoists	1,151.09		
Extras, etc.	1,500.00	90,936.09	505.20
Grading (Parks Dept.)	$873.79		
Scoria block (Works Dept.)	770.00		
		1,643.79	9.13
Furnaces		49,200.00	273.33
Chimney		10,700.00	59.44
Water connections		725.00	4.03
Drains		855.46	4.75
Scale		170.57	0.95
Hose		170.83	0.95
Test holes		623.00	3.46
Driving piles		9,749.23	54.16
Foundations		7,108.73	39.49
Totals		$212,982.70	$1183.22

Vancouver, B. C.—The Heenan back-feed, 40-ton incinerator has been used since 1907. The average weight of refuse burned per man per hour is 1.04 tons. The clinker is very hard, black, and well burned, the average percentage being 33. The evaporation per pound of refuse burned is given at 0.52 lb.

The cost per ton was as follows:

Building, etc.	$ 400
Chimney	98
Furnaces with boilers and accessories, complete.	532
Total cost per ton	$1030

3. Reduction Plants.—Nearly all the plants for the reduction of garbage have been built by contractors, and their detailed costs are not available. The costs of those built by municipalities are summarized in Table 144. The itemized costs, where they have been available, are given as follows:

Cleveland, Ohio.—The works have been operated as a municipal plant since 1905 when they were purchased from a private company. During this time the process has been changed twice. The costs, summarized below, give the purchase price and also the price of additions and improvements up to 1913. At present the Arnold or cooking process is used, and the plant has a capacity of 240 tons of garbage per twenty-four hours.

The following statement of the value of the Cleveland reduction plant is taken from the annual report for 1919 of Mr. Alex. Bernstein, Director of Public Service: During that year 60,932 tons of garbage were treated.

Item	Cost up to 1919	Cost per ton treated
Land at Willow	$36,100.00	$0.5925
Buildings at Willow	133,698.47	2.1942
Equipment:		
Machinery, tools, and implements	106,253.39	1.7438
Office furniture	376.00	0.0061
Inventory	35,570.16	0.5838
Totals	$311,998.02	$5.1204

Columbus, Ohio.—This plant was designed and built by the municipality in 1910. The buildings are of brick, and well built. The capacity of the plant is 160 tons of garbage per day, and its cost, reported in 1919, was $236,880, including a percolator plant which was added later.

TABLE 143.—ITEMIZED COST OF CONSTRUCTION OF GARBAGE REDUCTION PLANT, COLUMBUS, OHIO

Item	Cost, 1910	
	Total	Per ton of rated capacity
Buildings: Reduction bldg., green garbage bldg., gasoline storage, office, and half of stable	$71,177.48	$444.74
Percolator building	10,218.43	63.88
Brick chimney	4,600.00	28.75
Digesters, roller presses, grease separating and storage tanks, hot well, screw press, liquor storage tank	36,625.00	228.92
Receiving hoppers, jet condensers	1,000.00	6.25
Evaporators	9,400.00	58.76
Boilers and stokers	7,615.00	47.60
Driers and equipment	12,650.00	79.07
Conveyors and elevators	12,556.22	78.49
Percolator, vaporizing tanks, and condenser	6,030.39	37.69
Gasoline storage tanks	1,045.00	6.53
Reinforced concrete condenser tank	946.00	5.91
Motors and switch-board	2,903.00	18.14
Boiler feed pumps	574.00	3.59
Steel boiler flue	373.00	2.33
Open feed water heater	944.00	5.90
Water supply pump	1,317.00	8.23
Air displacement pumping equipment	4,046.00	25.29
Pipe lines	5,852.70	36.58
Oil storage tanks	172.00	1.08
Railroad track scales	987.00	6.23
Railroad track and trestles	5,182.80	32.39
Miscellaneous new equipment purchased from operating fund:		
in 1911	4,516.71	28.23
in 1912	1,426.82	8.92
in 1913	734.02	4.59
in 1914	1,416.09	8.85
Totals	$204,309.64	$1276.94
Engineering and miscellaneous	32,571.24	203.57
Totals	$236,880.88	$1480.48

(From Report of Garbage Reduction Plant, 1915)

Table 143 is an itemized statement of the cost of construction of the Columbus plant.

The principal cost items in 1910 were as follows:

Item	Total cost	Cost per ton of rated capacity
Buildings, grading, etc.	$81,267	$507.92
Reduction equipment	58,866	367.91
Power equipment	21,357	133.48
Conveying machinery	9,316	58.23
Wiring, electric	3,671	22.94
Non-conducting covering	1,011	6.32
Levee	9,712	60.70
Railway tracks	3,343	20.89
Office and advertising	16,143	100.83
Percolating plant	20,000	125.00
Sundry additional expenses, about	8,314	51.96
Totals	$233,000	$1456.25

Rochester, N. Y.—Early in 1920 a contract for a Cobwell reduction plant was let to the C. O. Bartlett and Snow Company, of Cleveland, for the following prices:

Buildings	$100,000
Reduction equipment	435,000
Conveyors	90,000
Motors	20,000
Totals	$645,000

Additional items, not included in the contract, will probably bring the total cost up to about $700,000.

The buildings are of brick and steel, and are on land owned by the city, just east of the old plant. The main reducer building is about 114 by 69 ft. The tankage storage building is 115 by 34 ft.

The equipment consists of 36 digesters, each having a normal capacity of 4 and a maximum capacity of 5 tons. It is assumed that about 10%, or 4, of the digesters may be out of use, undergoing repairs, leaving 32 for normal use, these 32 having a working capacity of 128 tons per day. It is assumed that, in case of a large supply of garbage during September of each year, all the digesters may be in use at

their maximum capacity of 5 tons each, making the peak load for the plant 180 tons per day.

The present population of Rochester is about 296,000.

Schenectady, N. Y.—This plant was designed and built in 1914. The cooking process is used, and the rated capacity of the plant is 60 tons per twenty-four hours.

COST OF SCHENECTADY PLANT

Item	Cost, 1914	
	Total	Per ton of rated capacity
Land	$10,500	$175
Machinery and boilers	57,000	950
Buildings, reduction equipment, gasoline storage building, receiving station, and office	46,500	775
Totals	$114,000	$1900

Under recent conditions, the C. O. Bartlett and Snow Company give $4500 per ton of rated capacity as a figure for estimate purposes.

The following gives some recent estimated costs:

Plant	Rated capacity, in tons per 24 hours	Construction Cost	
		Total	Per ton of rated capacity
Staten Island (1918)	2000	$3,000,000	$1500
Rochester (1919)	150	645,780*	4310
Syracuse (1919)	60	250,000	4167
Akron	135	472,000	3500

* Does not include boiler plant.

For cost estimates of reduction plants, see also E. Valuations.

TABLE 144.—SUMMARY OF CONSTRUCTION COSTS OF GARBAGE REDUCTION PLANTS

Plant	Date of erection	Rated capacity, in tons per 24 hours	Type of construction	Cost		Remarks
				Total	Per ton of rated capacity	
Cleveland, Ohio...	1905	240	Brick buildings	$250,333.29	$1043.10	Cost includes purchase price and cost of additions, to 1913
Columbus, Ohio...	1910	160	Brick buildings	236,880.88	1480.48	Includes percolator (1919)
Chicago, Ill......	1914	400	Brick buildings	279,689.00	965.09	Agreed cost of purchase
Schenectady, N. Y.	1914	60	Brick buildings	114,000.00	1900.00	Includes land at $10,500
Akron, Ohio......	1915	75	Brick buildings	91,909.00	1225.00	Has been enlarged
Dayton, Ohio....	1915	125	Concrete buildings	59,000.00	472.00	Gravel for concrete obtained on site
Los Angeles, Cal..	1915	250	Brick and concrete bldg.	425,000.00	1700.00	Cobwell system
Rochester, N. Y..	1920	120	Brick and steel	645,780.00	5380.00	Cobwell system

4. Feeding.—Very few actual costs of hog farms are available. The method has developed from small beginnings, and is largely in the hands of local farmers.

Table 145 gives the estimated first cost of the Danville, Ill., hog farm.

TABLE 145.—ESTIMATED FIRST COST OF HOG FARM FOR GARBAGE DISPOSAL, DANVILLE, ILL., 1916. POPULATION, 40,000

500 hogs at $8	$ 4,000
Team and harness	1,000
Hog house, with steam heat	5,000
Feeding-houses, two at $3,500	7,000
Wagon scales	1,000
Farm wagons	250
Farm house	2,500
Compost pits	1,000
Barn	1,500
Water supply	2,250
Land, 40 acres at $300	12,000
Fences, drainage, roads, etc	2,500
	$40,000
Contingencies, 10%	4,000
Total	$44,000

Estimates of the cost of the hog farm at Worcester, Mass., were made and summarized in 1917 by Frederic Bonnet, Jr., who has studied the Worcester farm in detail.

The following figures relate to the first cost of this hog farm, having a total capacity of 25 tons of garbage per day.

	Cost per ton of rated capacity
Buildings	$1200
Wagons and miscellaneous equipment	60
Hogs	2008
Total	$3268

The cost of operation, for a farm handling 20 tons of garbage per day, exclusive of fixed charges, and also based on the conditions obtaining at Worcester, may be taken as follows:

	Cost per ton
Superintendent	$0.351
Labor	0.789
Grain and bedding	0.362
Medicine	0.416
Light, heat, and power	0.137
Total	$2.055

5. Dumping.—No actual construction costs for dumping are available. The disposal of refuse materials by dumping will involve renting land or securing the privilege of dumping thereon. The first cost is limited to the caretaker's shelter and a few other items of dumping equipment. Along water fronts, retaining walls for shore protection are sometimes necessary.

6. Plowing into Soil.—For this method of disposal, also, we are not able to furnish actual construction costs. After the land is secured, very little is necessary for additional costs, other than the expense of plowing trenches.

D. OPERATION

1. Garbage Furnaces.—A summary of the annual costs of operating garbage furnaces, exclusive of fixed charges, is shown in Table 146. Assuming a construction cost of $600 per ton capacity, and interest and depreciation to amount to 10%, the fixed charges would be about 19 cents per ton. The labor required at a few furnaces is given below.

Minneapolis, Minn.—This plant, with a capacity of 65 tons, was operated in 1911 by three shifts in twenty-four hours, with the following force:

1 Superintendent
3 Engineers and crane operators
3 Helpers
6 Firemen
3 Utility men

Norfolk Va.—This plant was operated during 1914 and 1915 by the following force:

1 Superintendent,				
1 Foreman........................	365	days at	$2.50	per day
2 Helpers........................	312	"	2.10	"
1 Night Watchman................	365	"	2.10	"
1 Helper........................	92	"	2.10	"
1 Helper........................	79	"	2.10	"

The average quantity of garbage burned was only 20 tons per day.

Duluth, Minn.—The 80-ton Decarie furnace at Duluth was operated in 1912 by:

1 Engineer............................at $80.00 per month.
3 Firemen............................at 65.00 per month.

The average quantity of garbage burned was about 30 tons per day.

TABLE 146.—ANNUAL COSTS OF OPERATING GARBAGE FURNACES, EXCLUSIVE OF FIXED CHARGES

Plant	Year ending	Tons of refuse burned during year	Costs per ton			Remarks
			Labor	Fuel	Total*	
Easton, Pa.	Nov. 1, 1911	3,571	$0.63	$0.33	$0.96	Garbage and rubbish. *M. J.*,‖ Oct. 24, 1912, p. 604
Erie, Pa.	Oct. 14, 1914	4,745	0.70	0.30	1.00	Garbage only. *M. J.*, Dec. 3, 1914, p. 810
Portsmouth, Va.	Dec. 31, 1911	4,180 †	0.41	0.07	0.51	Garbage and rubbish. *M. J.*, Aug. 1, 1912, p. 150
Spokane, Wash.	Dec. 31, 1912	5,497	0.80	0.42	1.22	Garbage and rubbish. Cordwood for fuel. High cost for labor. *M. J.*, Feb. 13, 1913, p. 239
Rankin, Pa.	Dec. 31, 1912	1,800 †	0.40	0.09	0.52	Garbage. *M. J.*, Feb. 27, 1913, p. 299
Duluth, Minn.	Dec. 31, 1912	8,800 †	0.61	....	0.72	Garbage and rubbish. *M. J.*, Feb. 27, 1913, p. 299
Muskogee, Okla.	1911	....	0.34	0.08	0.42	Approximate costs. Results of test. Gas for fuel
Racine, Wis.	Dec. 31, 1914	2,900	....	....	1.29	225 lb. coal per ton of garbage. *Eng. and Con.*, Sept. 15, 1915, p. 211
Terre Haute, Ind.	1907	....	....	....	0.63	Garbage and night-soil. Result of test
Pasadena, Cal.	1913§	1,895	....	....	1.62	Garbage and rubbish. Distillate used for fuel *M. J.*, Apr. 17, 1913, p. 551; July 3, 1913, p. 22
Milwaukee, Wis.	1907	34,630	....	{1906 0.19}	1.35	Garbage only. Includes cost and repair of collection boxes. Report of Comm. of Health
Oak Park, Ill.	Dec. 31, 1907	5,600	0.30‡	0.40	0.70‡	
" "	1914	8,013	0.28	0.25	0.53	
" "	1917	9,432	0.28	0.39	0.67	
" "	1919	10,385	0.33	0.29	0.62	
Sewickley, Pa.	1907–1916	1,500	0.90	0.84	1.74	9-year average. *Eng. and Con.*, Vol. 46, p. 411

* All costs except interest and depreciation.
† Estimated from yardage.
‖ *Municipal Journal.*
‡ Approximate.
§ January 3, 1913, to June 3, 1913.

Richmond, Va.—There are two garbage furnaces in Richmond—a Morse-Boulger and a Decarie. They have a combined capacity of 50 tons per twenty-four hours. In 1915 each furnace required:

1 Foreman	at $2.75 per day.
2 Helpers	at 2.25 per day.

2. Refuse Incinerators.—A summary of the annual costs of operating refuse incinerators, exclusive of fixed charges, is given in Table 147. Assuming a construction cost of $1000 per ton capacity, and interest and depreciation to amount to 10%, the fixed charges would be about 32 cents per ton. Itemized statements of a number of annual costs are as follows:

Westmount, Que.—The operating costs of the Westmount incinerator are shown in Table 148, compiled from the financial report of the City of Westmount for 1919 and from local information. The fixed charges were computed by the auditors for the city.

It should be noted that, from 1907 to 1910, the incinerator consisted of one 50-ton Meldrum furnace, and that in 1910 a 50-ton Heenan furnace was added, making the present capacity of the plant 100 tons per twenty-four hours. This accounts for the increase in the interest and depreciation charges in 1910 over preceding years.

Table 148 also shows the revenue obtained from the sale of steam to the electric light plant. It is computed as follows: At different periods a twenty-four-hour run of weighed coal alone is made, and from this is found the number of pounds of coal required to produce one kilowatt-hour, as registered on the recording instruments. Until the next run is made, this figure is used to calculate the value of the refuse as a fuel when coal and refuse are burned at the same time. The incinerator is therefore charged with the value of coal when used.

Vancouver, B. C.—The operating costs per ton of refuse in 1910 have been given as follows:

For operation, not deducting revenue	$0.56
For interest and sinking fund	0.35
For revenue tax	0.10

The staff (eight-hour shift) consisted of 1 engineer, 6 firemen, and 1 dumpman.

West New Brighton, N. Y.—In computing the fixed charges, the interest on the plant is taken at $4\frac{1}{2}$%, on an annuity basis.

Table 149 gives the annual costs of the plant from 1909 to 1912, inclusive, and for 1918.

TABLE 147.—ANNUAL COSTS OF OPERATING REFUSE INCINERATORS, EXCLUSIVE OF FIXED CHARGES

Plant	Year	Tons of refuse burned during year	Total cost per ton	Revenue per ton	Net cost per ton	Remarks
Westmount, Que.	1914	23,800	$0.55	$0.48	$0.07	Steam sold to electric plant. Annual Rept., 1914
" "	1917	17,639	0.94	0.47	0.47	Also 383 dead animals
Milwaukee, Wis.	1913	53,581	1.23	0.20†	. . . .	Rept. Dept. Pub. Works, 1913
" "	1914	54,684	1.26	0.17	1.09	
" "	1915	58,043	1.15	0.20	0.95	Revenue estimated
" "	1916	54,275	1.24	0.20	1.04	" "
West New Brighton, N. Y. . .	1911	9,244	1.30	0.33	0.97	From sale of crude and crushed clinker. *Eng. Rec.*
Savannah, Ga.	1914‡	21,614	0.61	0.21	0.40	Steam used for pumping water. Rept. City Engr., 1914
" "	1915	27,661	0.77	0.17	0.60	From Annl. Rept., 1915
" "	1916	26,442	0.88	0.16	0.72	" " " 1916
Seattle, Wash.	1908	8,141 ¶	0.81	. . . .	0.81	
Portland, Ore.*	1910§	23,600	0.30	. . . .	0.30	

* Classification uncertain.
† Estimated revenue from new power plant.
‡ From March 24, to December 31, 1914.
§ From May 1, to October 31, 1912.
¶ Five months' operation.

TABLE 148.—OPERATING COSTS, FIXED CHARGES, AND REVENUE OF WESTMOUNT, QUE., REFUSE INCINERATOR

	1907*	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919
No. of tons of refuse	10,704	13,641	14,331	15,280	17,008	20,878	18,731	23,800	20,800	19,500	17,639	18,639	19,707
COST PER TON													
Fixed charges:													
Interest	$0.19	$0.17	$0.19	$0.25	$0.25	$0.21	$0.23	$0.18	$0.20	$0.22	$0.25	$0.23	$0.22
Sinking fund	0.04	0.08	0.06	0.08	0.07	0.05	0.05	0.04	0.05	0.05	0.06	0.06	0.05
Depreciation	0.13	0.12	0.15	0.21	0.21	0.17	0.17	0.15	0.15	0.17	0.20	0.19	0.18
Operating charges	0.55	0.52	0.46	0.48	0.59	0.48	0.65	0.55	0.65	0.71	0.94	1.31†	0.83
Total cost	$0.91	$0.89	$0.86	$1.02	$1.12	$0.91	$1.10	$0.92	$1.05	$1.15	$1.45	$1.79	$1.28
Revenue	0.36	0.31	0.40	0.40	0.46	0.40	0.45	0.48	0.48	0.46	0.47	0.32	0.29
Net cost	$0.55	$0.58	$0.46	$0.62	$0.66	$0.51	$0.65	$0.44	$0.57	$0.69	$0.98	$1.47	$0.99

* Ten months

† Including about 35 cents for expenses on ash dump.

TABLE 149.—ANNUAL COST OF WEST NEW BRIGHTON REFUSE INCINERATOR, IN TERMS OF COST PER TON OF REFUSE BURNED

Year	1909	1910	1911	1912	1918
Tons of refuse burned	9375	8827	9244	8960	7107
Fixed charges:					
Interest	$0.405	$0.430	$0.411	$0.424	....
Depreciation	0.174	0.185	0.177	0.182	....
Operating charges:					
Supervision	0.295	0.331	0.275	0.302	$0.528
Labor	0.857	0.930	0.918	0.935	1.370
Supplies and materials	0.058	0.052	0.064	0.090	0.083
Repairs and replacements	0.008	0.013	0.008	0.020	0.012
Apparatus, machinery, etc	0.004	....	....	....	*
Proportion of auto-maintenance, etc	....	0.003	0.003	0.005	*
Fuel	0.008	0.009	0.005	0.009	*
Contingencies	....	0.005	0.001	0.002	*
Office charges	....	....	....	....	0.082
Totals	$1.809	$1.958	$1.862	$1.969	$2.075

*Included in above.

The labor schedule for 1911 was as follows:

1 Engineer..........at $4.50 per day (part time on other work).
1 Assistant engineer...at 3.50 per day.
8 Furnacemen........at 900.00 per annum each.
1 Extra furnaceman...at 900.00 per annum (acts as watchman).

The plant was operated in two eight-hour shifts, and approximately 35 tons of refuse were burned per day.

Milwaukee, Wis.—As the incinerator in Milwaukee was the largest, and one of the first built on modern plans, in this country, the cost items are given in some detail in order to follow better its development. Tables 150, 151, and 152 give the earliest conditions, from 1911 to 1913.

Table 153 shows the operating expenses for 1919, exclusive of fixed charges; and Table 154 shows the cost per ton for 1917, 1918, and 1919, also exclusive of fixed charges.

The earlier tables give the required labor, its cost, and the total annual cost, including also fixed charges and materials. This information was obtained partly from data in the annual reports of the

TABLE 150.—LABOR SCHEDULE FOR FIVE MONTHS AT THE MILWAUKEE REFUSE INCINERATOR, 1911

	Percentage of total Labor cost	Cost per ton burned
Superintendent	2.9	$0.029
Foreman	2.5	0.025
Timekeeper and weighmaster	1.8	0.018
Boiler room routine	5.7	0.056
Cleaners	0.8	0.008
Cleaning hoppers	0.1	0.001
Clinker handling	17.1	0.168
Charging furnaces	20.2	0.199
Crane operation	5.3	0.056
Engine room routine	6.9	0.068
Furnace routine	35.7	0.351
Hoisting	0.3	0.003
Upkeep of grounds	0.7	0.007
Total labor	100.0	$0.985

TABLE 151.—LABOR SCHEDULE AT MILWAUKEE FOR 1912 AND 1913

	Amount paid per month	Number of men	
		1912	1913
Superintendent	$125.00	1	1
Chief engineer	100.00	1	1
Engineers	90.00	2	2
Weighmaster	75.00	1	1
Engineer's helpers	70.00	3	3
Furnacemen	75.00	24	24
Cranemen	70.00	3	3
Cranemen's helpers	60.00	3	3
Floormen	60.00	15	15
Ashmen	60.00	9	12
Hoistmen	60.00	2	2
Janitor	60.00	1	1
Totals	......	65	68

In 1913, one engineer's helper, one craneman, and one craneman's helper were occasionally added for temporary work during the summer.

TABLE 152.—ANNUAL COSTS OF OPERATING THE MILWAUKEE REFUSE INCINERATOR, IN TERMS OF COSTS PER TON OF REFUSE BURNED

Year	1912	1913
Tons of mixed refuse burned	48,513.22	53,581.02
Fixed charges: *		
Interest	$0.175	$0.158
Depreciation	0.218	0.197
Operating charges:		
Additions and improvements	0.074	0.080
Fuel	0.024	0.031
Plant expenses	0.014	0.027
Supplies	0.020	0.013
Repairs and replacements	0.035	0.020
Direct labor	0.707	0.710
Indirect labor	0.295	0.354
Totals	$1.562	$1.590

*Interest was taken at 4% on $212,006.63. Depreciation was taken at 5% on the same cost, and based on an average life of the plant of 20.4 years.

TABLE 153.—OPERATING EXPENSES OF THE MILWAUKEE INCINERATOR FOR 1919, EXCLUDING FIXED CHARGES

Personal service (superintendence and labor)	$87,022.96	
Cleaning and disinfectant supplies	13.22	
Fuel	8,294.93	
Office supplies	25.14	
General supplies	1,132.16	
Minor apparatus	20.10	
Tools	134.12	
General materials	613.61	
General repairs	0.00	
Minor repairs	2,271.93	
Municipal garage service	252.21	
Telephone	9.35	
Water	2,970.00	
General service	57.10	
		$102,816.83
Office equipment	20.00	
General equipment	805.95	
		825.95
		$103,642.78

Department of Public Works and partly from the studies made by the Bureau of Efficiency and Economy.

TABLE 154.—ANNUAL COST PER TON FOR OPERATING THE MILWAUKEE INCINERATOR, EXCLUDING FIXED CHARGES

Year	Mixed refuse delivered, in tons	Total cost	Cost per ton
1917	46,979.97	$72,079.07	$1.53
1918	45,457.58	81,047.60	1.78
1919	42,202.26	102,816.83	2.44

The labor schedule for 1919 was as follows:

1 Superintendent
4 Engineers
3 Cranemen
3 Cranemen's helpers
15 Floormen
27 Furnacemen
2 Wagonmen
12 Clinkermen
2 Fuelmen
1 Clean-up man
4 Oilers
1 Weighmaster
1 Scale helper
3 Change men
1 Repair man

The total number of men is 80; the average is 75.

Paterson, N. J.—During December, 1913, when burning 50 tons per day, the plant was operated by three shifts per day, with the following force:

1 Superintendent	at	$125.00 per month
3 Engineers	at	3.50 per day
3 Firemen	at	2.75 per day
3 Helpers	at	2.25 per day

When running at its normal rate, the furnace is operated on only one eight-hour shift per day, with the following force:

1 Superintendent	at	$125.00 per month
1 Engineer	at	3.50 per day
1 Fireman	at	2.75 per day
2 Watchmen	at	2.75 per day

These labor ratings were in force when the plant was being operated by the Destructor Company, prior to its acceptance by the City.

The quantity of refuse burned when operating with the Superintendent and 4 men was from 16 to 19 tons per twenty-four hours.

Savannah, Ga.—When burning an average of 75 tons of refuse per twenty-four hours, the labor schedule in 1915 was as follows:

1 Superintendent	3 Hoppermen
3 Engineers	3 Cranemen
9 Firemen	

One extra stoker was employed during July and August.

The following wages were paid for eight-hour shifts.

Superintendent, part of day	$2.50
Engineers	4.00
Cranemen	2.25
Firemen	1.75
Laborers	1.50

TABLE 155.—ANNUAL OPERATING COSTS OF GARBAGE REDUCTION PLANTS, EXCLUDING FIXED CHARGES

Plant	Year	Tons reduced during year	Total cost per ton	Revenue per ton	Net profit per ton	Remarks
Cleveland, Ohio...	1913	52,354	$2.000	$2.694	$0.694	
	1914	55,730	2.437*	3.491	......	
	1915	66,271	2.044	3.367	1.323	
	1916	60,717	2.418*	4.981	......	
	1917	56,121	3.188	5.203	2.015	
	1918	57,754	4.399	7.573	3.174	
Columbus, Ohio †.	1911	17,534	1.852	3.349	1.497	Does not include railroad transportation
	1912	18,789	2.049	3.285	1.236	
	1913	20,711	1.910	2.740	0.830	
	1914	21,629	1.859	3.085	1.226	
	1915	22,909	1.940	2.417	0.477	
	1916	21,861	2.215	4.051	1.836	
	1917	17,127	4.190	4.621	0.433	
	1918	15,630	5.47	7.18	1.71	
	1919	18,128	5.19	4.05	1.15‡	
Indianapolis, Ind..	5/26/18 to 12/31/18	12,187	3.548	7.174	3.626	
Chicago, Ill......	1914	75,600	2.046	1.278	0.768‡	
	1915	150,875	1.846	1.214	0.632‡	
	1916	137,920	3.138	2.977	0.161‡	
Dayton, Ohio....	1916	16,280	1.90	2.53	0.63	

* Includes depreciation.

† Figures for Columbus taken from *Eng. News-Record*, Nov. 18, 1920.

‡ Loss.

3. Reduction Plants.—A summary of the annual operating costs of garbage reduction plants is given in Table 155, no fixed charges being included. Assuming a construction cost of $1300 per ton, and interest and depreciation to amount to 10%, the fixed charges would be about 42 cents per ton of garbage. The fixed charge per ton would be higher, of course, if the plant were working below its rated capacity.

Cleveland, Ohio.—Table 156 is an itemized statement of the annual costs for Cleveland. There follows a statement of the itemized cost for 1919. The quantity of garbage treated was 60,932 tons.

TABLE 156.—ITEMIZED COST OF OPERATION OF GARBAGE REDUCTION PLANT AT CLEVELAND, OHIO

Item	Cost per ton				
	1912	1913	1915	1917	1918
Tons of garbage reduced	43,555	52,354	66,271	56,121	57,754
Supervision	$0.0780	$0.0458	$0.0311	$0 0395	$0.0416
Clerk hire	....	0.0191	0.0316	0.0346	0.0399
Office expense	0.0049	0.0028	0.0048	0.0046	0.0048
Labor—Operation	1.0403	0.8873	0.9746	1.3818	1.6624
Coal	0.1893	0.1287	0.3691	0.9037	1.3664
Gas	0.3328	0.4102	0.0836	0.1239	0.1122
Supplies	....	0.0025	0.1082	0.0889	0.2019
Gasoline	0.0745	0.1243	0.0988	0.1305	0.1942
Oil and waste } Miscellaneous expense }	0.0948	0.0064	*	*	*
		0.1001	0.0108	0.0179	0.0072
Insurance and taxes	0.0395	0.0314	0.0288	0.0296	0.0942
Freight on supplies	....	0.0038	0.0000	0.0001	0.0000
Maintenance:					
Buildings:					
Material	....	0.0183	0.0015	0.0093	0.0020
Labor	....	0.0305	0.0088	....	....
Machinery and equipment	0.1223	....	....	....	....
Material	....	0.1368	0.1253	0.2142	0.4396
Labor	....	0.0518	0.1670	0.2000	0.2325
Totals	$1.9764	$1.9996	$2.0440	$3.1876	$4.3989
Extraordinary expense:					
Flood damage	....	0.0418	....	....	....
Fire damage	....	0.0093	0.0211	....	....
Totals	....	$2.0507	$2.0651	....	....

* Included under supplies.

ITEMIZED STATEMENT, CLEVELAND PLANT, FOR 1919

	Cost per Ton.
Supervision	$0.0440
Clerk hire	0.0395
Operation:	
Labor for reduction	1.8692
Supplies:	
Office	0.0011
Fuel—coal	0.8751
Fuel—gas	0.0181
Light	0.0029
Gasoline	0.1384
Manufacturing	0.0175
Water	0.0524
Miscellaneous	0.0524
Overhead and miscellaneous	0.1186
Maintenance:	
Machinery and equipment—Labor	0.2413
Machinery and equipment—Material	0.1919
Buildings—Labor	0.0109
Buildings—Material	0.0177
Total reduction cost	$3.6910
Depreciation	0.2183
Total cost including depreciation, $238,202.73	$3.9093

Income from sale of garbage grease	$215,060.26
Income from sale of garbage tankage	78,721.17
Income from sale of garbage tailings	458.99
Income from prepaid freight	103.28
Income from miscellaneous	2,017.29
Total income	$296,360.99
Income per ton	$4.87
Profit per ton	0.96

The force employed at the Cleveland plant in July, 1918, was as follows:

Superintendent	1
Foremen	3
Engineers	3
Firemen	3
Helpers	3
Green garbage men	4
Blacksmith	3
Pipe fitters	3
Carpenters	2
Electricians	2
General labor	25
Skilled labor	52
Total number of men on pay-roll	104

Columbus, Ohio.—This plant is operated on 2 eight-hour shifts in summer and on 1 eight-hour shift in winter. The garbage handled daily in 1912 varied from 40 tons in winter to 90 tons in summer, with an average of 60 tons. Details of the operating costs are given in Table 157.

TABLE 157.—ITEMIZED COST OF OPERATION OF GARBAGE REDUCTION PLANT AT COLUMBUS, OHIO

Item	Cost per ton							
	1913	1914	1915	1916	1917	1918	1919	1920
Supervision.........				$0.317	$0.209	$0.264	$0.245	$0.148
Clerk hire..........	$0.192	$0.197	$0.227	0.030	0.058	0.078	0.076	0.074
Foremen...........				0.107				
Firemen..............	0.121	0.123	0.115	0.136	1.508	2.022	2.080	2.111
Operators............	0.189	0.220	0.200	0.194				
Ordinary labor........	0.559	0.490	0.490	0.600				
Fuel.................	0.331	0.313	0.306	0.418	1.457	1.363	1.085	1.889
Clothing.............	....	....	....	0.003	0.001	0.002	0.002	0.002
Mechanical supplies *..	0.052	0.045	0.053	0.043	0.093	0.142	0.116	0.124
Chemical supplies.....	0.118	0.109	0.108	0.140	0.010	0.420	0.364	0.395
Other supplies........	....	....	....	0.023		0.001	0.161	0.043
Motor vehicle.........	....	....	....	0.012	......	....	....	....
Advertising...........	....	....	....	0.001	......	....	0.035	0.008
Insurance............	....	....	....	0.009	0.005	0.001	0.010	....
Taxes and rent........	....	....	....	0.003	0.003	....	....	0.001
Light and power......	0.048	0.067	0.060	0.077	0.125	0.160	0.123	0.133
Other service.........	0.013	0.010	0.013	0.014	0.016	0.011	0.017	0.014
Maintenance:								
Buildings...........	....	....	....	0.000	......	0.002	0.030	0.004
Railway tracks......	....	....	....	0.001	0.016	0.215	0.053	0.044
Equipment—Labor...	0.120	0.101	0.107	0.094	0.394	0.777	0.767	0.540
Equipment—Material	0.115	0.128	0.201	0.163		....	....	....
Other maintenance....	....	....	....	0.000	0.007	0.002	0.012	0.003
Office expense.........	0.014	0.014	0.014	0.007	0.004	0.006	0.006	0.005
Transportation........	0.027	0.033	0.022	......	0.016	0.001	....	....
Miscellaneous.........	0.001	0.009	0.024	......	0.254		....	....
Telephone and telegraph	....	....	....	0.003	0.004	0.004	0.005	0.003
Hauling..............	....	....	....	......	......	....	0.005	....
Totals.......	$1.910	$1.859	$1.940	$2.215	$4.188	$5.469	$5.194	$5.539

* Including motor vehicle supplies.

The crews employed at the Columbus plant were as follows:

	Number of Men	
	Winter	Summer
Superintendent	1	1
Master mechanic	1	1
Assistant master mechanic	1	1
Blacksmith	1	1
General repair man	1	1
Foreman on night shift	1	1
Watchman	1	1
Firemen	2	2
Helper	1	1
Green garbage building cleaners	3	10
Digester tops on feeding	1	2
Presses and digester bottoms	1	4
Grease room	1	4
Evaporating room	1	2
Drying room	3	6
General labor	2	2
Totals	22	40

TABLE 158.—Cost to Cities for Garbage Reduction by Contract

City	Year	Tons per year	Annual Payment to Contractor		Remarks
			Total	Per ton	
Chicago, Ill.	1912	127,200	$47,500	$0.37	Disposal of garbage only
New York, N. Y.	1914	......	62,500*	.....	Includes transportation but not collection Manhattan, The Bronx, and Brooklyn only Increases $25,000 per year for next 3 years
Boston, Mass.	1914	......	134,000	......	Increases $3000 per year, includes transportation but not collection
Cincinnati, Ohio	1909	34,760	90,000	2.59	Collection and disposal of garbage only
Rochester, N. Y.	1913	30,000	77,500	2.58	Collection and disposal of garbage only.
Los Angeles, Cal.	1915	......	......	−0.51 *	City furnishes water free
Philadelphia, Pa.	1914	......	323,583	......	*Municipal Journal*
Buffalo, N. Y.	1914	......	18,000	......	" "
Atlantic City, N. J.	1914	......	20,000	......	" "
Baltimore, Md.	1914	......	37,000	......	$2000 increase per year
Washington, D. C.	1914	......	51,600	......	*Municipal Journal*
Syracuse, N. Y.	1914	......	13,975	......	" "

* Paid by contractor to city for garbage.

The costs per ton for garbage reduction, where it is done by contract and a fixed annual sum is paid by the city to the contractor, or *vice versa*, are shown in Table 158.

Table 159 gives the market prices of grease and tankage, in Chicago, Cleveland, and Columbus, for the years 1913 to 1919.

TABLE 159.—MARKET PRICES OF GREASE AND TANKAGE FROM GARBAGE

(From the *Canadian Engineer*, November, 27, 1919)

Year	Grease, in Cents per Pound			Tankage, in Dollars per Ton		
	Chicago	Cleveland	Columbus	Chicago	Cleveland	Columbus
1913	.....	4.26	3.75	.....	$6.00	$6.79
1914	.....	4.17	4.33	.....	6.75	7.41
1915	.....	4.41	3.76	.....	8.75	7.00
1916	7.29	6.50	5.16	$4.16	7.75	7.84
1917	7.34	8.00	7.50	4.16 *	9.58	10.85
1917				10.27 †	.....	.....
1918	11.57	13.50	11.75	10.27 *	18.50	19.80
1918				16.85 †	.....	.....
1919	.....	5.0 to 7.6	6.72	.....	10.00	15.65

* To August 1st. † Remainder of year.

4. Feeding.—Actual cost data for the operation of hog farms for garbage disposal are generally difficult to separate from the collection costs and the revenue from the sale of pork. An estimate of the cost of operation of a hog farm, based on experience at Worcester, Mass., by Frederick Bonnet, Jr., is given in Chapter VIII. Other data may also be found in that chapter.

5. Dumping.—The data available for the cost of dumping refuse materials cover mainly the upkeep of dumps, and do not include relative land values before and after dumping. Some typical costs of operation are given in Chapter VII.

6. Plowing into Soil and Burial.—Such data as we have for the operating cost of disposal of garbage by plowing into soil and burial are given in Chapter VII.

E. VALUATIONS

We are able to present valuations of only two reduction plants. No valuations are obtainable of incinerating plants, sorting plants, hog farms, nor of any other means of finally disposing of municipal refuse.

1. Chicago.—One of the few and most recent valuations of a refuse disposal plant owned and operated by a private company and taken over by a city, was made in connection with the purchase by the City of the plant of the Chicago Reduction Company. The appraisers, Col. Henry A. Allen, for the City, Mr. Harold Almert for the Company, and Mr. Leonard Metcalf, were unable to agree on a value. A record of their proceedings is published in the *Journal* of the Chicago City Council for October 1, 1913. The result of their work is summarized briefly as follows:

The agreed original cost, exclusive of development expenses, according to the best information then obtainable, is approximately as follows:

Real estate and buildings	$179,304
Machinery and fixtures	206,731
Total, August 31, 1913	$386,035

The agreed gross reproduction cost of the physical property, including agreed allowances of 7% for engineering, 5% for contingencies and omissions, and 4% for interest during construction, amounts to $296,370.

The accrued physical depreciation, based on the gross reproduction cost, including overhead allowances, has been estimated at the following amounts:

By Col. Allen	$122,071	41%
By Mr. Metcalf	72,000	24%
By Mr. Almert	41,585	14%

The depreciated reproduction cost of the physical plant, excluding real estate, development expense, etc., resulting from these three estimated allowances for accrued physical depreciation, determined by the several arbitrators, are as follows:

Col. Allen	$173,082
Mr. Metcalf	224,270
Mr. Almert	255,989

No allowance is made in these figures of net reproduction cost for the real estate, for by-products or supplies on hand, August 31, 1913, for functional depreciation, obsolescence, etc., or for the development expense or going value.

The value of the real estate, bordering on Bubbly Creek and 39th

Street, and aggregating 149,984.13 sq. ft., is estimated by Col. Allen at $112,488, and by Mr. Almert at $119,986, for ordinary manufacturing purposes. The average of these figures is $116,237, and it is agreed that 6% is a fair additional allowance to be applied to the land to cover interest on its cost during the construction period of the plant, and 5% to cover engineering, legal, and other expenses incident to the acquisition of the necessary land for such a project. Adding these percentages, the average price of the land for ordinary manufacturing uses would amount to $129,023.

The Company contends, however, that a substantially higher value should be placed on this property for the purposes of garbage reduction, by reason of its peculiar adaptability and location, both as a center for collection and disposition, and on account of its proximity to the stockyards district.

Col. Allen takes the position that no additional allowance should be made on account of these considerations.

Mr. Metcalf suggests that an allowance of $15,000 would, in his judgment, be reasonable.

Summing up, therefore, these several independent views, the following net or depreciated reproduction costs of the physical property of the Chicago Reduction Company, excluding all allowances for or in consideration of development expenses or going value, result:

Col. Allen's	$305,000
Mr. Metcalf's	383,000
Mr. Almert's	463,000

As previously stated, the Board was unable to agree on a fair value of the property, under the terms of the contract entered into between the City of Chicago and the Chicago Reduction Company under date of August 30, 1913.

Col. Allen stated that

"The City of Chicago is not compelled to purchase or to make use of the plant of the Chicago Reduction Company for the taking care of its garbage in a sanitary manner. The city officials are in possession of data, based upon properly conducted experiments conclusively proving it is practicable to immediately handle the garbage of the City in a sanitary and inoffensive manner, should the present plant be destroyed or otherwise become unavailable for use by the City . . . Further consideration should be given to the fact that there is a strong public sentiment favoring abandoning the reduction process, and caring for and disposing of the City's wastes, including garbage, by means of incineration. The City Council has already authorized the purchase of several tracts of land for the installation of incinerators,"

and that the property should be valued upon the basis of the fair value of the land for manufacturing purposes, and the value of the plant should be of its temporary utility to the City. Upon this basis he valued the property of the Chicago Reduction Company at the approximate sum of $208,582, as follows:

" Real Estate	$112,488
11% allowance thereon for interest-during-construction and cost of acquisition	12,374
Organization expenses. (Proportionate part)	8,400
Temporary utility of parts of plant	67,070
Scrap and salvage value	8,250
	$208,582

Mr. Almert valued this property, on the basis of its income in the light of its past history, at $750,000.

Mr. Metcalf called attention to the fact that the contract, entered into between the parties at issue, stated in its preamble, first, that

" The City of Chicago desires to purchase the plant of the said Reduction Company for the purpose of operating the same to dispose of the City's garbage, and the Chicago Reduction Company has agreed to sell the same,"

for which reason it was clearly to be assumed that the contracting parties were, respectively, in the position of willing buyer and willing seller; and, second, that

" The appraisal is to be made upon the plant as a going concern, taking into consideration the reasonable development expenses incurred by said Company in bringing said garbage reduction plant to its present condition, with all of the natural accretions thereto, and is to include the lands upon which said plant is now located, taking into consideration the peculiar adaptability for the purposes for which it is now used, with all of the appurtenances thereunto both above and below ground, buildings, machinery and all tools, stores, supplies, and merchandise on hand, all assignable outstanding contracts;"

and that, therefore, the property should be valued as one having a developed business, or one which was producing from garbage, by-products which found a ready market at prices showing profit to the Company independent of any payment to the Company, by the City, for the services rendered; and that, under the terms of this agreement, it was unfair to assume that the property would be valued on the assumption that it was to be abandoned by the City, or to be utilized merely for its temporary convenience.

Without attempting to make refined figures on the various bases of estimate outlined, Mr. Metcalf expressed the opinion that the fair value of these works, determined on the basis contemplated in the joint agreement, might be fixed at approximately $475,000 as of August 31, 1913.

The authorities of the City of Chicago did not see their way clear to accept Mr. Metcalf's valuation, and undertook energetically to dispose of the garbage by dumping. Under these conditions, the Reduction Company agreed to accept a lower figure, and the plant was finally purchased by the City for $279,689.

2. Rochester.—In Rochester, N. Y., in 1918, a valuation was made of the reduction plant. The plant had been in use for some years, and was taken over by the City. The arbitrators were Mr. I. S. Osborn for the City, Mr. G. D. Beaston for the Contractor, and Mr. W. J. Springborn as the third member. They agreed on the price as $127,414.

Subsequently, a new reduction plant was built, near the old one, on lands owned by the City, and with railroad sidings provided. The Cobwell system was selected and built at a cost of $645,000.

F. PRELIMINARY ESTIMATES

Investigations for refuse disposal generally require estimates of the first cost of construction and of the annual cost of the various methods of disposal which would be sanitary and satisfactory for the local conditions. They are frequently made in order to determine the relative costs of several methods, as the basis for a selection. Therefore they sometimes do not include those items which are the same in all estimates, and, consequently, do not represent the actual final costs. Some of these estimates are summarized in the following:

1. Chicago.—In 1914, Messrs. I. S. Osborn and J. T. Fetherston made an exhaustive study of the refuse collection and disposal problem in Chicago. Their final report, embodying the results of this investigation, discussed six projects, "A" to "F," for the collection and disposal of refuse, and recommended Project "D" as the one best suited to the needs of the city. A brief description of the projects follows. Table 160 gives the estimated costs of the different projects.

Project "A."—This project covers the total incineration of rubbish and garbage, and a portion of the ashes. The city is divided into eleven districts, with a loading station in each district and incinerator plants in nine of the districts. It contemplates the collection of garbage and rubbish combined, and a separate collection of the ashes.

TABLE 160.—ESTIMATED COSTS OF PROPOSED COLLECTION AND DISPOSAL OF REFUSE IN CHICAGO, 1914

Item	Projects					
	"A."	"B."	"C."	"D."	"E."	"F."
Capital cost:						
Collection equipment	$614,000	$603,750	$669,750	$683,500	$683,500	$683,500
Stables	600,000	600,000	660,000	660,000	660,000	660,000
Loading stations	390,000	330,000	255,000	600,000	660,000	615,000
Street cars	160,000	140,000	160,000	140,000	140,000	160,000
Motor trucks	....	....	....	72,000	72,000	72,000
Water transportation equipment	....	....	....	100,000	112,000	100,000
Incinerator	2,790,000	6,320,000	2,354,375	395,000	395,000	498,625
Reduction plant	....	....	....	862,500	802,500	862,500
Totals	$4,554,000	$7,993,750	$4,099,125	$3,513,000	$3,525,000	$3,651,625
Annual cost, including operation, maintenance, and fixed charges:						
Collection	$1,753,188	$1,582,386	$2,042,446	$1,766,286	$1,766,286	$1,761,747
Loading stations	80,416	69,499	58,601	92,713	92,713	96,810
Street car transportation	294,445	182,097	263,455	226,724	226,724	229,314
Motor truck	....	....	....	56,695	85,345	56,695
Water transportation	....	....	....	58,259	58,259	165,902
Incinerators	489,103	1,369,729	419,454	88,892	88,892	87,926
Reduction works	....	....	....	372,192	372,192	387,665
Totals	$2,617,152	$3,203,711	$2,783,956	$2,661,761	$2,690,411	$2,786,059
Revenue	140,325	640,711	166,520	725,654	725,654	782,475
Net annual costs	2,476,827	2,563,000	2,617,436	1,936,107	1,964,757	2,003,584
Annual costs per capita	$0.85	$0.88	$0.89	$0.67	$0.68	$0.69

Project "B."—This project covers the total incineration of all garbage, ashes, and rubbish, and the collection of all three classes of refuse combined. The number of collection districts, loading stations, and incinerators is the same as in Project "A," except that the capacity of the incinerators was increased in order to dispose of the larger quantity of ashes to be incinerated.

Project "C."—This project covers the total incineration of all garbage and rubbish, with a portion of the ashes. It differs from Projects "A" and "B" in assuming different collection districts. The city was divided into nine collection districts, with a loading station in each. In seven of the districts it contemplates the erection of incinerators adjoining sewage and water pumping stations, which might be available for utilizing the steam produced by incinerator plants. It contemplates the combined collection of garbage and rubbish, and a separate collection of ashes.

Project "D."—This project covers the disposal of garbage in a central reduction plant, and the disposal of rubbish in small incinerators at each loading station, except in the district comprising the Eighth and Ninth Wards, which is provided with an incinerator for the combined incineration of all garbage and rubbish. The city is divided into fourteen collection districts, with a loading station in each, for transfer of the material by trolley, barge, auto-truck, or wagon. It contemplates the separate collection of ashes, rubbish, and garbage, except in districts where total incineration is proposed. All ashes are to be disposed of by filling.

Project "E."—This is the same as Project "D," except that the location of the works is assumed to be on the drainage canal near the western city limits, necessitating the transfer of garbage for a longer distance, also a larger quantity to be transferred, which, under Project "D," would be delivered directly to the plant.

Project "F."—This is similar to Project "D." The difference is in the disposal of rubbish. In this project the rubbish is transferred from loading stations to one of four incinerators, where it would be burned and the power utilized. All garbage from all districts is to be disposed of in a central reduction plant.

It was assumed that the population would be 2,905,000 in 1920, and 3,503,000 in 1930. The production of refuse, in pounds per capita per year, was assumed as follows: Garbage, 150 lb.; ashes, 700 lb.; and rubbish, 50 lb.

The cost of operating the incinerators and the reduction plant was based on the cost of overhead charges, labor, fuel, supplies, repairs, and renewals required to dispose of the quantities to be produced in 1920.

The capacities of the various plants were based on the estimated maximum production of the different classes of refuse for 1930.

The value of clinker was based on current prices for similar or equal materials used for pavement foundations, sidewalks, and similar concrete work.

The grease and tankage to be recovered from the garbage were estimated to be 3.25% and 14%, respectively, of the total weight of the garbage as delivered.

The price of grease was assumed at 4 cents per lb. and the price of tankage at $7 per ton.

Interest was assumed at 5%, and the depreciation (also at 5%) was based on a sinking fund which would equal the cost of the elements making up the plant.

2. Toronto.—A report on the best means of disposing of the refuse of Toronto was submitted to the Mayor of that city by Hering and Gregory, Consulting Engineers, New York City, in 1911. The report included a careful study of the relative merits of incineration and reduction for the final treatment and disposal of the garbage, and also studies of the possible utilization of other city wastes not included under garbage. The choice of methods of disposal narrowed down to the incineration of garbage mixed with other and more combustible refuse, with no utilization of the heat of combustion, and the treatment of garbage alone by the reduction process for the recovery of grease and tankage for fertilizer base, and with the separate incineration of combustible refuse. The low price at which hydro-electric power is available in Toronto, acting against the utilization of steam, turned the cost in favor of the second alternative. If the salable portions of the combustible refuse were sorted out and sold, and only the remainder burned, the estimates indicated a small profit from the combined operations of the reduction works and incinerating plants; otherwise, there would be a slight yearly expense.

A summary of the projects follows:

Project " A."—Incineration of the garbage, rubbish, and a portion of the ashes without utilization of the rubbish; the plant to consist of two 215-ton incinerators.

Project " B."—Incineration of the garbage, rubbish, and a portion of the ashes, with utilization of the rubbish; the plant to consist of two 195-ton incinerators; no utilization of steam.

Project " C."—Reduction of the garbage, and incineration of the rubbish, without utilization of the rubbish; the plant to consist of one 240-ton reduction works and two 60-ton incinerators.

Project " D."—Reduction of the garbage, and incineration of the rubbish, with utilization of the rubbish; the plant to consist of one 240-ton reduction works and two 40-ton incinerators.

Table 161 gives comparative estimates of the first cost and the

annual operating costs of the four projects, based on a population of 600,000.

TABLE 161.—COMPARATIVE ESTIMATES OF THE FIRST COST AND ANNUAL OPERATING COSTS FOR FOUR PROJECTS FOR THE DISPOSAL OF GARBAGE, ASHES, AND RUBBISH, OF TORONTO, ONT., 1911

Projects	Estimated cost of construction	Estimated Annual Costs			
		Gross cost of operation	Gross income	Net cost of operation	Net income
Project "A": Two 215-ton incinerators	$478,400	$124,940	......	$124,940	......
Project "B": Two 195-ton incinerators	489,300	166,750	67,500	99,070	.....
Project "C": One 250-ton reduction plant	538,200	169,970	210,000	......	......
Two 60-ton rubbish incinerators	228,700	47,180	......	......	......
	$765,900	$217,150	$210,000	$7,150	......
Project "D": One 250-ton reduction plant	538,200	169,970	210,000	......	......
Two 40-ton rubbish incinerators	255,300	92,570	67,500	......	......
	$793,500	$262,480	$277,500	......	$15,020

The City, fearing that a possible nuisance might result from the operation of a garbage reduction plant, and after building the incinerator for the destruction of rubbish, utilized the latter plant also for the incineration of garbage, notwithstanding the greater cost. The cost of building the incinerator is given on page 520.

3. Trenton, N. J.—A comparison of reduction and incineration in their relation to the future sewage disposal needs of Trenton was made in 1913 by Hering and Gregory. Using this comparison as a basis, they advised that all garbage and rubbish, with at least 20% of the ashes, be burned in a high-temperature incinerator having a ca-

pacity of 120 tons per day; that a power plant be built to transmit the electric current generated by the heat of the incinerator to a pumping station at the proposed sewage treatment works; and that a clinker mill be built to prepare the clinker from the incinerator for use in concrete foundations under street pavements or otherwise.

The 1913 population of Trenton was taken at 110,000, and it was assumed that in 1930 it would be 150,000. During 1912 and 1913 the total weight of garbage and rubbish collected was 270 lb. per capita per year. The total weight of ashes for the same period was 730 lb. per capita per year; the combined weight of garbage, ashes, and rubbish is, accordingly, 1000 lb. per capita per year. Estimating this as the quantity collected, the 1930 population might supply 13,500 tons of garbage, 6750 tons of rubbish, and 54,750 tons of ashes per year. By using the maximum figures for 1912, a maximum weight of mixed refuse per day of 123 tons is indicated.

The clinker produced, suitable for paving work, was estimated at 5000 cu. yd. per year, and its value was taken at $1.00 per cubic yard.

Table 162 gives the comparative costs of construction of plants for disposal, respectively, by reduction and incineration. Tables 163 and 164 give the detailed estimates of relative operating costs.

4. Summary.—The many considerations and elements entering into the cost of refuse disposal works in America make it impossible to give any figures for preliminary estimates which can be applied to our many different situations. In general, however, the average range of costs of refuse disposal in 1910 was estimated as in Table 165. In 1920 the costs were very much greater.

G. EUROPEAN DATA

In England and on the continent of Europe there has been a wide experience with refuse incinerators. A number of plants have been inspected by the authors, and for several of them the following notes, chiefly on labor requirements, were made. They were brought up to date in 1911.

1. Birmingham, England. — (Population, 525,000.) Plant consists of two units, each of four grates, only three of which are used; there is a boiler connected with each unit; about 65 tons per day are burned; clinker and dust amount to 34% of the refuse. Labor schedule per eight-hour shift: 1 man charging and 2 clinkermen; a foreman works on the day shift only; total, 10 men.

2. Poplar (London), England. — (Population, 770,000.) Plant consists of six cells, side by side in a row, and two water-tube boilers;

TABLE 162.—ESTIMATED CONSTRUCTION COSTS FOR REFUSE DISPOSAL AT TRENTON, N. J. (1913)

Method	For disposal of refuse	For pumping sewage	Totals
Incineration	$195,500	$172,500	$368,000
Reduction	241,500	174,800	416,300
Saving in favor of incineration	46,000	2,300	48,300

TABLE 163.—ESTIMATED NET ANNUAL OPERATING COST FOR INCINERATOR PLANT AT TRENTON, N. J. (1913)

INCINERATOR

Operation:				
Supervision and labor	$13,680			
Removal of ashes	600			
Maintenance and repairs	1,700			
Crushing and cleaning clinker	2,000			
		$17,980		
Fixed charges:				
Interest, 4.5% on $195,500	$ 8,800			
Sinking fund, 3.356% on $195,500	6,560			
		15,360		
			$33,340	
Income from sale of product:				
Clinker			5,000	
Total estimated net annual cost of operation of refuse incinerator				$28,340

SEWAGE PUMPING

Operation:				
Labor in power plant at incinerator	$ 2,520			
Labor in sewage pumping station	3,720			
Coal for Sunday operation	1,140			
Oil, waste, packing, miscellaneous supplies	750			
		$ 8,130		
Fixed charges:				
Interest, 4.5% on $172,500	$ 7,760			
Sinking fund, 1.783% on $172,500	3,080			
		10,840		
Total estimated annual cost of operation of sewage pumping station				18,970
Total estimated net annual cost of operation of refuse incinerator and sewage pumping station				$47,310

TABLE 164.—ESTIMATED NET ANNUAL OPERATING COST FOR REDUCTION PLANT AT TRENTON, N. J. (1913)

Additional cost of separate collection for garbage and rubbish:			
Cost of separate collection	$65,140		
Cost of combined collection	49,950		
		$15,190	
Transporting garbage from loading station to reduction works:			
Labor at loading station	$800		
Labor operating motor trucks	3,360		
Supplies for and maintenance of motor trucks	6,030		
		10,190	
Garbage reduction works:			
Supervision and labor	$18,960		
Coal	12,750		
Naphtha	1,100		
Supplies and miscellaneous expenses	2,500		
Repairs and renewals	1,500		
		36,810	
Fixed charges:			
Interest, 4.5% on $241,500	$10,870		
Sinking fund, 3.356% on $241,500	8,100		
		18,870	
			$81,160
Income from sale of product:			
Grease	$28,350		
Tankage	10,400		
		......	38,750
Total estimated net annual cost of operation of reduction works			$42,410

RUBBISH INCINERATOR

Operation:		
Labor	$1,395	
Supplies and miscellaneous expenses	170	
Repairs and renewals	400	
Removal of ashes	405	
Total estimated annual cost of operation of rubbish incinerator		$ 2,370

SEWAGE PUMPING

Operation:			
Labor in power plant at reduction works	$ 5,760		
Labor in sewage pumping station	3,720		
Coal	7,140		
Oil, waste, packing, and miscellaneous supplies	750		
		$17,370	
Fixed charges:			
Interest, 4.5% on $174,800	$ 7,870		
Sinking fund, 1,783% on $174,800	3,120		
		10,990	
		......	$28,360
Total estimated net annual cost of operation of reduction works, rubbish incinerator, and sewage pumping station			$73,140

TABLE 165.—ESTIMATED AVERAGE RANGE OF COSTS OF REFUSE DISPOSAL IN THE UNITED STATES IN 1910

Items	CONSTRUCTION COSTS	ANNUAL COSTS OF OPERATION				
		Cost per ton handled, excluding collection expenses				
	Cost per ton of rated capacity	Fixed charges	Operation	Total gross cost	Revenue	Net cost
Garbage furnaces.........	$400 to $800	$0.12 to $0.24	$0.75 to $1.25	$0.89 to $1.47	....	....
Refuse incinerators.......	800 to 1600	0.24 to 0.35	0.60 to 1.00	0.84 to 1.35	$0.20 to $0.50	$0.34 to $1.15
Garbage reduction works..	1040 to 2280	0.29 to 0.38	1.75 to 2.50	2.04 to 2.88	3.00 to 4.00*	0.12 to 2.00

* Profit only from garbage reduction. No account is taken of cost of ash and rubbish disposal.

capacity, 150 tons daily; plant handles 120 tons daily. Labor schedule per shift: 1 craneman, 2 clinkerers, 2 wheelers, 1 boilerman; and, on the day shift, 1 foreman and 1 helper; total, 20. The steam produced, amounting to 1.5 lb. per pound of refuse, is supplied to an electric lighting station.

3. Frankfort, Germany.—(Population, 410,000.) Serves entire city; handles 120 tons per day; plant comprises five units, each with four grates or cells. Labor schedule: 2 men charging, 6 men clinkering, and 1 craneman, or 9 per eight-hour shift; total, 27. The steam produced per ton of refuse generates 70 kw.hr., 8 of which are required for plant operation.

4. Barmen, Germany.—(Population, 142,000.) Plant of special local design; handles 40 tons in summer, up to 80 tons in winter; 6 cells and three boilers; clinker ranges from 50% of total refuse in summer up to 70% in winter. Labor schedule: 2 men charging, 4 to 6 clinkermen, 8 to 10 general laborers; total, 14 to 18. The men all work in eight-hour shifts. The plant is reported to generate 400 kw.hr. of electrical energy, which is valued at about 0.7 cent per kw.hr.

5. Zurich, Switzerland.—(Population, 150,000.) Serves entire city; capacity, 90 tons per day; original plant consisted of twelve "Horsfall" cells, hand-charged; two cells fitted with automatic charging apparatus in 1908, and others to follow.

Labor Schedule

Old Cells	*New Cells*
4 Firemen	4 Firemen
2 Clinkermen	1 Clinkerman
4 Stokers	0 Stoker
2 Helpers	1 Helper
1 Craneman	1 Craneman
1 Weigher	1 Weigher
1 Superintendent	1 Superintendent
15	9

Firemen, clinkermen, and stokers work on eight-hour shifts—two in summer and three in winter. Other men work a nine-hour day. Dust and fine ashes are sold for about 25 cents per cubic yard. Crushed clinker brings 50 cents per cubic yard. Tin and scrap iron bring about 35 cents per 100 lb. The clinker crushing plant cost $16,000, and requires three men for operation; the revenue from dust, clinker, tin, and iron, is about $4000 per year.

6. Labor Required in European Plants.—A summary of the labor required for operation in a few of the foregoing plants is given in Table 166.

TABLE 166.—LABOR SCHEDULES AT SOME EUROPEAN REFUSE INCINERATORS

See also Tables 100 and 101

Plant	Total number of men employed	Average number of tons per day burned	Average number of tons burned per man per hour
Birmingham	10	65	0.81
Poplar	20	120	0.75
Frankfort	27	120	0.56
Barmen	16	60	0.47

H. SUMMARY AND CONCLUSIONS

To estimate the actual total costs of the final disposal of refuse, it is necessary to state them as annual charges. First, all the fixed charges should be ascertained, such as interest on investment, depreciation, etc., and secondly, the operating costs, such as supervision, labor, power, supplies, etc. In this way the relative cost values of different methods of disposal can be most safely ascertained.

The investment cost includes the expenses for engineering and legal services, for land, and construction. It can be given either in gross sums or, better, as costs per ton of rated capacity.

The operating costs per annum are usually given for salaries, wages, materials, etc., but they should be given also, as far as practicable, in terms independent of the varying wages, i.e., as man-hours or ton-hours. To find the cost at any time, it is then necessary only to multiply the prevailing wage rate at that time by the number of man-hours.

Regarding valuations for purposes of sale, we have inserted the case of the Chicago Reduction Works as the best available example according to which valuations of refuse disposal works may be determined.

We have added some labor data from incinerating works in England, Germany, and Switzerland for comparison with the labor engaged on our works.

Fetherston states, after an inspection of twenty-seven plants in England, that each man could handle 0.88 ton per hour, and that, at

an easy rate of working, there should be no difficulty in burning 0.75 ton per man per hour. This conclusion may not necessarily apply to American conditions. Yet, we are strongly of the opinion that it would be more helpful in regulating our work, if we would record our labor data as tons burned per man per hour, instead of in day's wages, and thereby directly indicate the efficiencies of method, apparatus, and labor, which we indicate less perfectly at present, or not at all.

CHAPTER XIII

SELECTING THE METHOD OF DISPOSAL

A. INFLUENCE OF LOCAL CONDITIONS

The choice of the most suitable method of refuse disposal for a given place is governed by certain general and special conditions. Thus we find that in Europe the incineration of mixed refuse, or disposal by land-fill, or burial, are practically the only methods in use. In England and Germany labor is cheaper than in America, but, in many parts, coal is more costly and this favors incineration. In the largest cities of America, the reduction method has been most common, for two reasons: Our greater per capita waste makes the recovery of marketable products from garbage profitable; and the rapid expansion of our cities has in some respects rather favored a separate collection of garbage, ashes, and rubbish, which makes the reduction method possible and practicable.

In the early stages of city growth, the disposal of garbage requires attention before that of ashes and rubbish. On account of the frequent lack of available community funds, the two latter are often left to the householder for private disposal. Compared with Europe, our cities are spread over wider areas, so that many places for dumping ashes and rubbish are usually available. This method of a separate disposal, therefore, has been allowed to continue, while European cities, with more congested areas and fewer vacant lots, favored a mixed collection. Mainly on these grounds, they have generally adopted incineration.

Feeding garbage at piggeries has been particularly prevalent in the New England States. This may be due to the fact that hog food costs more in New England than elsewhere, and, therefore, that more money can be paid for the collection of garbage. Further, we find that most of the reduction plants in America are economical chiefly in the largest cities in the Northern States. In the South, garbage contains more vegetable and less animal waste, and, therefore, less grease. It is also possible that the higher average temperature of the air in the South has been the cause of more rapid decomposition and conse-

quently more intense odors at the works, requiring more expense for proper control than in the North. The high price of food caused by the late war has resulted in general economy, with a consequent reduction of the wasted grease, and less profit for reduction works.

The burial of garbage is more suitable for small and isolated cities than for large ones, because of the long hauls usually required for the latter. Incineration of mixed refuse is suitable for both large and small cities. Even within the built-up parts of cities it has been practiced without objection, with the result that the hauls are shorter.

Cities in the South, and those in districts where natural gas is available, cannot produce as much waste heat and power as those using coal for domestic purposes. Therefore, incineration may not be economical everywhere. In cities where most of the cooking and heating is done by gas or oil, and the opportunities for burning rubbish at the house are restricted, the combustible value of collected rubbish may be correspondingly increased. A favorable location of cities with reference to a good market for grease and tankage may strongly influence the adoption of the reduction method.

Finally, in the same city, different districts may find different disposals advisable. Even in the same district this may be found advantageous. For instance, a small part of the garbage—the best part, as from hotels and restaurants—will, for economical reasons, probably always be fed to animals, whatever may be the disposal of the bulk of it. Another part, which has become unsuitable for either feeding or grease extraction—due to age or admixtures, and where dumping is also impracticable—will probably always be incinerated, for sanitary reasons.

B. OTHER CONTROLLING ELEMENTS

In some cases the method of disposal is forced on the community by conditions beyond the control of the city officers, and this may have an important influence directly on the system of collection and house treatment. For instance, if reduction or hog feeding is used, it is necessary to have a strictly separate collection of garbage. In some districts of New York city ash cans often contain some garbage, and garbage cans receive enough ashes and rubbish to make it necessary to pick over this material before the garbage can be utilized for grease extraction or for hog feeding.

Since, in New York City, the reduction works on Staten Island went into the hands of a receiver, and the garbage has been temporarily disposed of at sea, there has been a gradual tendency to mix the different classes of refuse in the house cans and collecting

carts, because more convenient. Similar conditions have been encountered also in Boston.

The rejection of such mixtures by the collectors would evidently cause some inconvenience to the inhabitants, and would necessitate not only a special collection, at increased cost, but also a separate disposal for such mixed material, probably by incineration.

If the local conditions indicate the best method of disposing of the refuse to be incineration, then it is an advantage to mix it at the house. In the case of separate collection, the householder may be requested to drain garbage of its free moisture before placing it in the house can, as is done in Minneapolis, Trenton, and other cities. If the rubbish is to be picked over for recovering the salable matter, as at Buffalo, the householder should be required to deposit all the rubbish in the can as free from other matter as possible. Where the garbage is to be fed to hogs, and the collector can pay a price for it, there is an inducement to the householder to keep it separate and clean.

A system of collection requiring an extra can at each house will increase the community cost by the value of the cans, by their replacement every few years, and sometimes by the fact that it is necessary to have a greater number of wagons and collections.

Sufficient records are not yet available to indicate in every case the economical relation between the disposal method and the manner of collection or the house treatment. For each community, the economies of this relation should be specially determined.

C. ACTUAL REPORTS

In view of the foregoing statements it is interesting to note the recommendations for refuse disposal made in various cities in America. In December, 1907, Hering studied the conditions in Milwaukee, and summarized the recommendations, as follows:

> "Two projects are available: First, the reduction of garbage at Mequon [7 miles from the city] and the incineration of other refuse at the foot of Erie Street. Secondly, incineration of all refuse at the foot of Erie Street. Both projects should give satisfaction, and both would be in line with future necessities and provide a sanitary solution of the refuse disposal problem of your city. It remains, therefore, that their relative preferences should be determined by their cost. . . . From the cost summary it will be seen that the reduction project is the more expensive one. . . . In view of the facts and conclusions set forth above, it is my opinion that a plant built at the foot of Erie Street for the incineration of garbage, together with all other objectionable waste, will not only be a satisfactory solution of your problem, but will be the most economical one, the more so as the works are increased and receive, besides the garbage and rubbish, also the domestic ashes."

In 1911, Hering and Gregory made an exhaustive report on refuse disposal for Toronto. The following summary and recommendation is taken therefrom:

" In view of the facts above set forth, we find that for the City of Toronto, the reduction process for converting the garbage into salable products, the incineration of rubbish, and the utilization of the ashes for filling land or for other purposes, is materially cheaper than incinerating both the garbage and the rubbish, together with a sufficient part of the ashes required to generate the necessary heat for a complete incineration of the organic matter.

" Besides the financial side of the question, which it was the main purpose of this report to deal with, there are other sides which should be kept in mind, and therefore should be at least briefly mentioned.

" The reduction system requires that the garbage and ashes be separated at the house and placed in different receptacles, that separate collections of these three classes of refuse be maintained, that strictly enforced ordinances must be established, to avoid any mixing of the several classes of refuse at the house, and that, to facilitate this enforcement, collection of the different classes of refuse should be made on different days.

" When the interests of the householder are considered, the fact, well recognized in Europe, and here and there also on this side of the Atlantic, must be admitted, that a single receptacle for all of the refuse is apt to encourage greater cleanliness about the premises, as well as greater simplicity in the servants' work and a better obedience to the respective city ordinances.

" With a separate collection, as in New York City, it cannot be denied that there is a constant and troublesome tendency, well recognized by the collection department, to throw rubbish and ashes into the garbage pail or garbage and rubbish into the ash pail. Similar experience is reported also from Boston and elsewhere. A mixed collection avoids the above troubles. The financial value of this condition must be determined by yourselves.

" The reduction system further requires the city to enter into the business of selling grease and tankage in the best markets in the world, of entering into competition with other producers, and of taking the chances of the market. It is true that in Cleveland and Columbus this fact does not seem to have caused any disadvantages. In our comparison of cost, we have not taken the actual profits derived in those cities, but have slightly reduced them for Toronto. The financial value, also, of this condition, namely, the undertaking by the city of a business enterprise on the present known facts, must also be estimated by you.

" The unfortunate and unwarranted experience with most of the reduction works in the past and present, namely, the escape from them of offensive effluvia, may have the effect of a weighty opposition to the establishment of such a plant on the part of neighboring property owners. While there is no real ground whatever for such opposition at the works considered for the City of Toronto, and of which perhaps Columbus may give the best proof, yet it must also be left to you to estimate the financial value of such opposition.

"On the other hand, to assist you in estimating these values, let it be said that experience in the United States has shown no lack of opposition to placing refuse incinerators in or near inhabited districts. This opposition is due to the nuisances generally caused by the older and unscientific designs for such incinerators, which are not inherent to the incineration method. In all of the latest designs for high-temperature furnaces, all offensive odors can be as readily prevented as in the latest designs for reduction works. Incineration plants are situated in built-up parts of cities in England and Germany without any objection, and on the American continent we can point chiefly to Westmount (Montreal), Richmond (New York City), and Milwaukee, Wis., as furnishing examples of odorless incinerators.

"Again, an incinerator plant which reduces its annual cost by the sale of power and clinker also requires the city to sell both products. Steam is sold for heating or, by conversion into electricity, for power, and clinker is sold for making roads, artificial stone, concrete, etc. This feature is relatively favorable toward incineration. The steam or electricity in most cases is not sold in competition but is utilized for municipal works, for pumping or lighting, while the clinker is also used for public works; therefore, the element of competitive business in such cases is largely eliminated.

"Finally, and irrespective of cost, there is a difference between the two types of works in the collection system, for as one is more complex than the other, their relative value, to you, should also be estimated by you."

An investigation, made in 1914 for Chicago, by Osborn and Fetherston resulted in the following recommendations:

"1. That the City should own and operate a complete refuse collection and transportation equipment, also refuse disposal works.

"2. That regular and systematic collection of separated classes of wastes (ashes, garbage, and rubbish), be made at daily or tri-weekly intervals, depending on the character of the districts served and the seasons of the year.

"3. That the laws regarding house treatment in respect to the separation of the different classes of waste be strictly enforced.

"4. That separation of all classes of refuse be made by the householders, except in districts where the combined refuse is disposed of by incineration.

"5. That separated garbage be treated by the reduction process at a central plant, located for service by barges to be used in transporting the material from waterfront loading stations, except such garbage as may be economically hauled by wagon or truck direct to the plant.

"6. That separated ashes be disposed of by filling low lands or depressions in need of grading, and, as far as practicable, that such lands be purchased by the City, so as to secure the benefit from the enhanced value derived from the improvement.

"7. That small incinerators be constructed at each loading station for burning the separated combustible rubbish. Other classes of rubbish, including metals, glassware, etc., should be reclaimed at the loading stations and sold. The unsalable and incombustible rubbish should be disposed of with the ashes.

"8. That the present garbage loading stations be remodeled, and that at

least three additional garbage loading stations be provided on the river or canal.

"9. That a loading station for ashes be provided in each district where street-car transportation is more economical than direct team haul to dumps.

"10. That garbage receiving stations for motor trucks be provided, to reduce the team haul.

"11. That a modern high-temperature refuse incinerator be installed at Stony Island Avenue and 95th Street, to dispose of the combined refuse from that district.

"12. That the mechanical analyses and tests of refuse started early this year be continued for a period of at least one year or longer, to determine the seasonal variation of the several classes of waste.

"13. That a competent technical staff be employed to develop, install, and operate for at least one year the project herein recommended, and to make such further studies and tests necessary to determine in detail the most suitable types of receptacles and equipment for a model collection service.

"14. That the maintenance division, in charge of the collection and disposal systems installed, be provided by the technical staff with carefully determined standards of performance and unit costs, in order that proper control may be exercised over the work.

"15. That three million five hundred and thirteen thousand dollars ($3,513,000) be provided for the purpose of collection and transportation equipment, and the construction of Reduction Works and Incinerator Plants. Of this sum, eighty-five thousand dollars ($85,000) should be made available for the first year's expenses of the technical staff."

An investigation in Danville, Ill. (1916), by Greeley, resulted in the following recommendations:

"1. That an ordinance should be adopted, establishing proper sanitary methods for the house treatment of refuse and the stable treatment of manure.

"2. That 10 collection wagons be purchased, at an estimated cost of $3,850. Specifications should be prepared and bids received.

"3. That a permanent system for garbage collection should be established, to give regular service twice a week. The wagons should be owned by the city, and the horses and collectors should be hired. Collectors should be required to wear khaki or duck uniforms.

"4. That garbage should be disposed of for the present by burial at two fields located on each side of the city. The estimated cost of weighing scales, roadways, etc., at the burial fields is $4,180. Garbage should be given to farmers who call for it in proper wagons at these fields, thus reducing the amount of garbage to be buried.

"5. Proposals should be entertained for disposal of garbage by contract at some isolated location at an annual cost favorable to the city. Such arrangement should include a formal contract in which the character of plant and equipment is clearly defined to be of a type that can be operated on a sanitary basis. The contract, however, should not include collection.

"6. A site with an area of about one acre should be purchased along the

Chicago and Eastern Illinois Ry., at some location near the center of production of refuse. The site should be used for shipping tins and rubbish to the market. It should be reserved for a future incinerator, when disposal of garbage by burial or otherwise is no longer feasible, due to the increased population, and scarcity of land for burial.

"7. As the garbage collection service becomes established, the collection of tins and rubbish should be started, and they should be shipped to the market for sale. After a site is secured, plans and specifications should be drawn up for a loading station for these materials."

The foregoing recommendations for refuse disposal at Danville offer a program which can be developed progressively as funds permit. The collection of garbage can be started at once. For the immediate future, the garbage collected can be disposed of by burial. In the meantime a site can be purchased along the railroad for the establishment of a loading or transfer station for rubbish and tins. The collection of these materials, even at infrequent intervals, is desirable, and will eliminate the cost and trouble of an annual clean-up campaign. This site would be available at any time for the construction of an incinerator.

Perhaps the most significant of the foregoing Chicago recommendations is the one calling for a technical staff. It has been partly adopted, and the money appropriated by the Common Council. A similar recommendation has been adopted at Toronto. Many failures and much waste of public money could be avoided if the refuse disposal problem were given more technical study by city officials.

D. DATA REQUIRED

It is essential to know all the general and local conditions which determine the choice of the method of disposal, and this is possible only by collecting and tabulating the necessary data governing the case. These data should extend over a period of at least one year, in order to embrace the different seasonal conditions. As the average yearly production of refuse is likely to differ much from the maximum and minimum, it is not always safe to use it, when estimating the capacity of disposal works, although, occasionally, this has been done. If the power of a plant to generate electric light, and to be operated by the steam from an incinerator, should be estimated from the average annual quantity of refuse, the electric power produced during the summer or autumn would fall short.

The best method of refuse disposal for a given locality can be determined only after a careful technical and engineering investigation, based on sufficient information covering the house treatment,

the collection, the transportation, and the final disposal, as herein set forth at length. The data should include, besides the cost of the plant, also the cost of operating it continuously, as well as the fixed charges.

The details of refuse disposal plants are being improved continually, and all cities, including the smallest ones, can well afford to keep accurate measurements and records, thus obtaining the required data, so that they may be ready to improve and enlarge their disposal systems whenever it is found economical or desirable to do so.

The contract system for disposal works, in which the taxpayers are not personally interested, is desirable only when there is a marked economy and when the term of the contract is long enough to guarantee the return of the money invested on a forced sale.

E. CONCLUSIONS

It may be helpful to recapitulate the general conclusions reached in the foregoing, regarding the respective values of the different methods of disposal.

The first and most important value is the degree of sanitation which can be attained. The second value is based on the cost, and the third on questions of expediency.

We can state the relative sanitary and economical values of the disposal methods by themselves, irrespective of the collection methods, as follows:

1. Dumping all refuse into water or on land has the least sanitary value of the available methods. It also yields no profit, except possibly a slight one in the case of land making.

2. Shallow burial of garbage can be a good sanitary method under careful supervision. It may yield a slight profit when fertilizing sandy soil. The disposal of ashes and rubbish requires a separate treatment.

3. Hog feeding at specially arranged farms, if properly operated, can satisfy all sanitary requirements. It is the most profitable method of fresh garbage disposal. The disposal of ashes and rubbish requires a separate treatment.

4. The reduction of garbage to grease and tankage, if properly arranged and operated, can satisfy all sanitary requirements. After hog feeding, it is the most economical method of garbage disposal. The disposal of ashes and rubbish requires a separate treatment.

5. Incineration of all refuse is the most sanitary process for disposing at once of all objectionable matter. Under some conditions, and in most cities of Europe, it is also the most economical method.

When planning works for the future, it is often necessary to esti-

mate the value of expediency, depending on the general local tendencies toward a possible change in conditions and habits. Where low areas or ravines can be filled with refuse without objection, and at a saving of cost, it would be justifiable to use this method temporarily, or until the conditions change. Where it is evident that the use of coal will be superseded by the use of oil or gas, it would be quite proper, with reasonable allowances, to build works for the conditions of the near future, instead of the present.

With the tendencies to conserve the grease in the kitchen and to feed more garbage to hogs, yet not to lessen the rejected combustible rubbish, there will be a corresponding tendency to increase relatively the combustible parts of refuse and to decrease the quantity of wasted grease, thus favoring incineration rather than reduction, as has been demonstrated in Europe, with its more settled social habits.

When the public is willing to pay a higher price for a better method of collecting and of disposing of the refuse, it would be justifiable to adopt the more expensive method.

The cost of labor is less for a modern incinerator, with mechanical apparatus for feeding and clinkering, than for a reduction plant. Therefore, the gradual increase of labor cost in the future will tend to become relatively less for incineration than reduction works, and it will be evident, assuming a case where, for a given city, the estimates of total cost, including the collection, and the revenues for incineration and reduction are equal, that the future tendency will be toward the cost of incineration becoming less than that of reduction.

To summarize:

In order to select the best method of disposing of the solid refuse of a community, we must base the preference on three requirements: Sanitation, economy, and expediency.

Table 167 indicates conspicuously the several sanitary methods of treatment. Incinerators, it will be seen, can dispose of all kinds of refuse, without exception. If the temperature in the furnace is maintained at a sufficiently high point, it gives the best insurance for a complete destruction of pathogenic bacteria and for the avoidance of nuisance from the putrefaction of organic matter. It should be preferred, therefore, unless, at a smaller cost, similar advantages can be gained by another method.

The second requirement is economy. We can ascertain it by computing the annual expenses of several of the best sanitary and otherwise satisfactory methods, and the annual receipts that may accrue therefrom. That method which requires the least net annual expense will be the preferable one for adoption.

TABLE 167.—PRODUCTS RESULTING FROM VARIOUS METHODS OF DISPOSAL

Kind of refuse	INCINERATION produces	REDUCTION produces	SHALLOW BURIAL OR PLOWING INTO SOIL produces	DUMPING produces	FEEDING produces
Garbage.........	Steam and ashes, when mixed with other refuse.....	Grease and fertilizer	Decomposition and fertilizer	....	Hogs for human food
Rubbish.........	Steam and ashes, with or without prior picking .	....	....	Land *	....
Ashes, domestic..	Steam and clinker	....	....	Land	....
Stable manure...	Moderate heat and ashes.....	....	Decomposition and fertilizer	Land *	....
Street manure....	Ashes.........	....	Decomposition and fertilizer	Land *	....
Night-soil.......	Ashes.........	....	Decomposition and fertilizer	......	....
Dead animals....	Ashes.........	Grease and fertilizer	Decomposition and fertilizer	......	....

* Only conditionally advisable.

The annual expenses should include:

1. Cost of collection from points of origin and delivery to the point or points of final disposal.

2. Interest on the cost of the works and equipment.

3. Depreciation fund to replace any parts, or the whole of the works and equipment, when they require renewal.

4. Cost of repairs, to maintain a continued efficiency of the works and equipment.

5. Cost of receiving, treating, removing, or selling the produced materials.

6. Administration, taxes, legal expenses, and sundries.

The annual receipts should include:

1. Appropriation of funds by city or individuals.

2. Proceeds of sales of pickings.

3. Proceeds of sales of products.

The third requirement, that of expediency, must be left entirely to the judgment of the local governing bodies, after they have carefully weighed the questions of sanitation and cost, which should be considered mainly in the light of tendencies toward possible changes in local and cost elements.

CHAPTER XIV

STABLE REFUSE

A. MATERIALS

Stable refuse or manure, as here understood, consists of animal droppings, straw, and the general cleanings from stables. It should be distinguished from street sweepings, discussed in Chapter XV, although the latter, if coming from well-paved streets, have many of the characteristics of manure. The nature of stable manure depends on the kind of animals producing it and the kind of bedding used. The bedding is generally straw, and (rarely) leaves or shavings. In most cities, cows, sheep, goats, and such animals are not now allowed to be housed in the built-up districts, so that horse manure, mixed with the bedding material, practically constitutes the stable refuse.

Stable refuse, both as to its quantity and its nature, is a material of sufficient importance to require careful attention from the municipal cleansing department. It is unsightly, and, if improperly cared for, creates odors by the production chiefly of ammonia. It is most dangerous, however, in being a common breeding place for flies. Under ordinary city conditions, particularly in warm climates, it has been estimated that 90% of the flies found in houses comes from stables or their vicinity. The elimination of the common manure pile goes far toward the elimination of flies as disease carriers and also as a great nuisance. The stable manure problem, being largely a fly problem, therefore requires careful consideration.

1. Quantity.—Few records are available as to the quantity of manure produced in a city. The weight and volume produced by one horse in a stable depend very much on the kind and quantity of bedding, the drainage provided, and the care with which the manure is gathered. Table 168 gives the estimated quantities for a few cities some years ago. Mr. L. O. Howard states that "the average city horse produces about 15 lb. of manure daily. The larger working horses produce from 20 to 30 lb. per day, but, as they are out of the stable much of the time, the actual quantity of stable manure would be much less."

In his report on the disposal of refuse in Milwaukee (December, 1907), Hering had measurements made of the quantity of manure produced in a week by three horses, and found it to be 21.5 lb. per horse per day. There were in Milwaukee at that time about 12,500 horses, so that the total quantity of manure produced in the city was estimated to be 133 tons per day. It was estimated that in Chicago in 1908, there were 83,330 horses. In 1912 this number had fallen to 72,670, owing to the increased use of automobiles and motor trucks. Based on 22 lb. of manure per horse per day, there would have been produced in Chicago in 1912 about 800 tons of manure per day. It was found in Milwaukee that manure, reported as "dry," weighed 970 lb. per cubic yard.

TABLE 168.—Production of City Manure

City	Year	Population	Estimated Quantity of Manure per Day	
			Tons	Pounds per 1000 population
Milwaukee, Wis..	1907	350,000	133	760
Columbus, Ohio..	1910	182,000	75	825
Chicago, Ill......	1912	2,000,000	800	800

It has been estimated in Columbus, Ohio, that one horse would produce 30 lb. of manure per day, and that there were in 1910 about 5000 horses in the city. The total quantity, therefore, was about 75 tons per day. Some manure in that city is collected by the Refuse Collection Department. During 1912, this Department removed 18,600 cu. yd., weighing 7440 tons, which is equivalent to 800 lb. per cubic yard. The total quantity collected amounted to about 25 tons per day, indicating that the Department was removing only about one-third of all that was produced in the city.

In a recent report Mr. Babson says:

"The rapidity with which motor trucks are replacing horses is indicated by statistics recently issued by the Sanitary Bureau of the New York Health Department. According to their report, the number of stables in New York was 7926 in early March, 1919, compared with 10,584 at the same time two years ago. The total number of horses declined from 108,036 to 75,740 during this same period. The loss was greatest in the Boroughs of Queens, Brooklyn, and Manhattan. The number in Richmond Borough decreased only 19%, and in The Bronx only 5%. It will be but a short time before the motor truck in great part replaces the horse in industrial and commercial

work. There will always be a certain field for horses, but it is becoming more limited."

With a rate of reduction of about 30% in horses in two years in New York City, the quantity of stable refuse will be greatly diminished in the future.

2. Character.—Manure is valuable chiefly as a fertilizer. It has also some calorific value, as shown by analyses in the test of the Milwaukee refuse incinerator. (Table 169.) The average of these analyses shows that it contains 53.1% of moisture and 10.1% of carbon, as compared with garbage containing 70.6% of moisture and 4.1% of carbon. In spite of the fact that manure contains less moisture and more carbon than garbage, it is found equally difficult to burn. This is probably caused by the manure forming a heavy mat over the fire, through which air penetrates only with difficulty, and with correspondingly poor combustion.

TABLE 169.—ANALYSES OF MANURE AT MILWAUKEE, WIS., IN 1910

(All quantities given in percentages by weight)

Items	Date of Sampling						Averages
	May 18	May 24	May 24	May 26	May 27	June 1	
Moisture......	49.29	53.63	49.57	57.02	58.57	50.50	53.10
Carbon.......	9.27	11.52	10.18	10.83	7.34	11.34	10.08
Volatile matter	27.95	27.78	33.54	22.65	28.13	33.30	28.90
Pure ash......	13.49	7.07	6.71	9.50	5.96	4.86	7.90

Manure has a much larger volume per unit weight than garbage, so that, with an equal volume of fuel crowded on the fire, there is present a less weight of manure and a smaller proportion of carbon.

The value of manure as a fertilizer depends largely on its organic constituents available for plant food. These are largely nitrogenous, and there are also potash and phosphoric acid. Typical analyses of stable refuse are shown in Table 170.

3. Flies.—An unfortunate characteristic of manure is its suitability as a breeding place for house and stable flies.

The life of a fly comprises four stages: The egg, the larva, the pupa, and the adult fly. The larva is commonly called the fly maggot.

Fly eggs are deposited in almost any fermenting organic matter. Forbes experimented on fly breeding in a large number of different materials. He found flies to have a decided preference for manure,

kitchen slop, street carrion, and rotten chicken feathers. Large quantities of fly eggs are deposited in garbage. The garbage delivered to the refuse incinerator at Milwaukee was often observed to contain many fly maggots. Each female fly may lay from 120 to 150 eggs in each deposit, and, in one season may deposit as many as four times, thus approaching 600 eggs from a single fly.

TABLE 170.—Analyses of Fresh Manure

Percentages by weight

Items	Source of Data			
	Harris *	Emyle Birt	Henry and Morrison †	Dr. Voelcker ‡
Moisture	66.2%	75.4%	75.0%	66.17%
Organic matter, soluble	28.2	16.5	....	2.48
" " insoluble				25.76
Inorganic matter, soluble	5.6	8.1	....	1.54
" " insoluble				4.05
Totals	100.0	100.0	....	100.00
Nitrogen	0.64%	0.59%	0.55%	.45 to .65%
Phosphoric acid	0.33	0.44	0.30	.2 to .5
Potash	0.67	0.48	0.40	.4 to .8

* "Talks on Manure," 1910.
† "Foods and Feeding."
‡ Dr. J. A. Voelcker of the Royal Agricultural College, England.

The duration of the egg stage may be as short as eight hours. Newstead, in Liverpool, found that the eggs hatched in periods varying from eight hours to three or four days, the average time being about twelve hours.

The young larva or maggot is slender, tapering from a blunt, round posterior end to a pointed head end. It is white, about 2 mm. long, and extremely active. It burrows at once into the substance on which the egg was laid. During the growth of the maggot, the skin is cast twice, so that the maggot passes through three distinct stages of growth. In the third and last stage, the larva is white or yellowish.

The rate of development of the maggot varies with the temperature, and with the character of the material in which it is growing. Howard found in Washington that the larval period was approximately three

days. The transformation to the pupa stage may take place anywhere, but it has been very generally established that there is a definite effort on the part of the maggot to descend deeper into the manure pile or other substance in which it may be living. Cory and Levy have established the fact that, for pupation, many maggots burrow into the earth beneath stalls and stable floors. This habit has suggested an advantageous means of catching the maggot. A pan filled with a poisonous material, or even with water, is placed below the manure box, so that, when the maggot crawls out of the bottom of the pile it drops into the poisonous liquid or water below and is destroyed.

When the maggot becomes a pupa it is about 6 mm. in length. Its color, at first, is yellowish, but rapidly changes to red and finally to a dark chestnut. The adult fly develops within the pupa. With a favorable temperature, the adult fly may emerge between the third and fourth day (usually four or five days) after pupation. The pupæ have no power of locomotion, but remain where the maggots stopped, unless moved by some outside force. The pupæ will generally be found around the outside of the manure pile, forming a ring, or in the earth just below. The migration toward the outside of the pile may be a provision to let the fly emerge more easily.

The adult fly issues from the pupa about ten days after the egg is laid. Dr. Stewart observed a minimum rate of growth, as follows:

Eggs	8 hours
First stage of larval period	20 hours
Second stage of larval period	24 hours
Third stage of larval period	3 days
Pupal stage	3 days
Total	8 days 4 hours

Newstead has observed a minimum period of from ten to fourteen days, and a maximum period of from four to five weeks.

Computations have been made of the possible number of flies which can develop during a season from a single female. The number runs into the billions. One ton of warm moist manure has been estimated to contain 900,000 maggots. The destruction of a single fly in the beginning of the fly season, therefore, means a large reduction in the number in the latter part of the season.

Observations indicate that flies travel for considerable distances; during calm weather, as far as 1000 yd. in open districts; in windy weather very much farther. The range is probably somewhat less in the built-up parts of cities and towns.

The foregoing notes have been taken largely from "The House Fly," by L. O. Howard, and "The Reduction of Domestic Flies," by Edward H. Ross.

As a result of many investigations, it has been found that flies transmit typhoid fever, dysentery, and other intestinal diseases. This danger is well summed up in the headline of a fly poster prepared by the State Board of Health of Florida, which reads :

"From Filth and Flies to Food and Fever."

4. Stable Treatment.—The stable treatment of manure in a city is important. It should be determined with full consideration of the habits of the fly, and all reasonable measures should be taken to prevent the fly from breeding. The manure should be stored in receptacles as nearly fly-tight as possible, although this precaution alone will have little effect on the number of flies produced. Its chief advantage lies in the curtailment of the food supply and breeding area. The size of the receptacle depends on the frequency of removal. It is important to make such receptacles of a non-absorbing material, as this prevents the development of ammonia odors from liquid compounds which might be absorbed by the material. The retention of the liquids in the manure adds considerably to its fertilizing value.

The migratory habits of house-fly larvæ should always be well considered. Levy and Tuck have proposed and used with good results a so-called maggot trap. It is based on the observed fact that the maggots developing in manure issue from it as adult larvæ and pupæ, through any small holes or crevices in the bottom of the receptacle holding it, and immediately seek the nearest point at which they can enter the earth and burrow into the soil. Levy and Tuck believe that the soil is the normal place for pupation. In order to prevent this further development of the fly, they arranged a floor for the receptacle containing the manure, consisting of stout wire screening of $\frac{1}{2}$-in. mesh, and placed below it a container with several inches of water. Into this the maggots dropped and were promptly destroyed by drowning or poisoning. Cory in 1918 * fully described this method of controlling the house-fly nuisance by the maggot trap.

Experiments with a similar apparatus were made by Hutchison for the United States Department of Agriculture. Table 171 shows the result of an experiment on the migratory habits of fly maggots. In this experiment 99% of the maggots were destroyed before they reached the pupal stage.

This migratory habit of the maggot has an important bearing on some of the details of the construction of horse stables. Cory

* *Bulletin 213* of the Maryland State College of Agriculture.

and Levy concluded that the substitution of cement floors for earth or wooden floors would cause a material reduction in the development of flies. If the floor of the stable is not tight and sound, manure containing fly eggs may get through it to the ground below. Urine will also get through, and all the conditions favorable to the development of the larvæ may be established, namely, food, warmth, and moisture. If the openings in the stable floor are large, flies themselves will enter the space between the earth and the floor, and deposit their eggs on a suitable material.

TABLE 171.—MIGRATORY HABIT OF HOUSE-FLY LARVÆ

From Bulletin of the U. S. Department of Agriculture, Professional Paper No. 14, "The Migratory Habit of Housefly Larvæ as Indicating a Favorable Remedial Measure. An Account of Progress," by Robert H. Hutchison, Scientific Assistant.

Date, 1913	Larvæ collected from pans	Flies caught in traps	Date, 1913	Larvæ collected from pans	Flies caught in traps
			Brt. fwd.	6710	11
Nov. 14	162	......	Nov. 26	......	2
" 15	656	......	" 27	......	3
" 16	1950	......	" 28	......	2
" 17	2650	......	" 29	......	2
" 18	1240	......	Dec. 1	......	2
" 19	40	......	" 2	......	8
" 20	*	7	" 3	......	5
" 21	12	0	" 4	......	6
" 22	0	0	" 5	......	15
" 23	0	0	" 6	......	10
" 24	0	0	" 7	......	3
" 25	0	4			
Carried fwd.	6710	11	Totals...	6710	69

* Collected on the following day

5. Germicides and Traps.—Many experiments have been made to find a satisfactory germicide to kill fly eggs and maggots in manure. Chloride of lime, carbolic acid, kerosene, iron sulphate, and carbon bisulphide are all more or less expensive, when used in sufficient quantities to be effective in destroying the maggots. It has been found that 1 lb. of chloride of lime, when applied to 6 lb. of horse manure, will kill 90% of the maggots in less than twenty-four hours. On this basis, from 3 to 5 lb. of lime would be required per horse per day, and, with lime at three cents per pound, this method of treatment would be expensive for a large stable. Kerosene is cheaper, though it

is a dangerous fire hazard and impairs the fertilizing value of the manure.

In Montclair, N. J., during 1915, a vigorous effort was made by Mr. Chester H. Wells, Health Officer, to prevent fly breeding in stable manure, two inspectors being appointed for this purpose. It was found impracticable to make satisfactory arrangements for the frequent removal of the manure A long series of experiments was made with different kinds of maggot killers, in order to find the cheapest and yet the most effective material. It was found that several coal-tar preparations would do the work, if the manure was wet thoroughly with a solution of the proper strength, but that the stable help could not be relied on to give the matter sufficient attention. It was finally decided that sodium arsenate was both the most effective and the cheapest material that could be used. If the manure is sprinkled each day with a solution consisting of a tablespoonful of sodium arsenate in 2 gal. of water, no fly breeding should result. It was found that the manurial value was not decreased.

Howard quotes some unpublished experiments by Forbes, of Illinois, which show that "the breeding of the house-fly in manure can be controlled by the application of a solution of iron sulphate—2 lb. in a gallon of water for each horse per day—and by the use of 2½ lb. of dry sulphate per horse per day."

Professor C. F. Hodge, of Clark University, Worcester, Mass., has conducted some interesting experiments on the stable treatment of manure. He is convinced that it is useless to undertake to remove the breeding places of flies. He points out the difficulty of keeping them away from the manure when the trap door built on the manure boxes must be opened several times daily. He, therefore, devised a fly trap, which can be attached to the manure box. He contends that it is easier and more effective to trap and kill adult flies and thus eventually to exterminate them, than to attempt to remove the breeding places, although the latter is naturally of great assistance.

From a review of the evidence, particularly in southern cities, where the fly problem is of greatest importance, it is evident that more effective methods for the reduction of flies should be used. Well-built, well-drained, fly-proof receptacles for the manure should be used. The stable floors should be made tight, so that flies will not develop in the ground beneath. Fly and maggot traps should be set at proper points about the stables, and the manure should be removed as promptly and regularly as possible.

The data thus far presented apply particularly to house and stable flies. There are other kinds which develop in fermenting organic matter, and are found in stables and garbage disposal plants. The

treatment, as far as we know. should be practically the same as that just mentioned.

Where manure cannot be collected regularly, and must be stored for periods of considerable length, it is best to use either fly-tight receptacles or the maggot trap, to prevent fly breeding.

B. COLLECTION

1. Methods.—There are few instances of a municipal collection of manure, as it is generally removed directly by the stable owners or for them by farmers. In large cities, supplementary transfer of the manure to long distances becomes necessary. Frequently, the city cleansing department arranges to have freight cars stationed at one or more sidings throughout the city. The stable users deliver the manure to the freight car and the farmer takes it from a siding in the outlying farming or truck-garden districts. In smaller towns, and to a considerable extent in larger cities, the farmer removes it directly from the stables. Such a method of collection is not wholly satisfactory, because the farmer cannot find time for it during the busy seeding and harvesting seasons. It is also unsatisfactory to rely on the stable users for prompt and regular collection.

In Milwaukee, the cleansing department has constituted itself as a sort of clearing house, where farmers desiring manure can secure the names and addresses of stable users desiring to have it removed. This plan has worked quite satisfactorily. Whenever it was possible, the department secured annual contracts, between the farmer and the stable owner, to insure the removal of manure throughout the year. Livery stables generally, and quite properly, remove manure every day or two during the fly-breeding season.

In Buffalo, N. Y., all manure is collected from city barns and private stables by farmers, who are under contract with the City and, in 1914, paid $2.50 per horse per year to the City, and the same to the householders. The manure is collected daily from the City barns.

In Columbus, Ohio, the removal and disposal is governed by the following ordinance:

"Be it ordained by the Council of the City of Columbus, State of Ohio:

"Section 1.—That it shall be unlawful for any persons in possession of or controlling the use of any barn, stable, pen, shed, stall, or similar place within the City of Columbus, Ohio, wherein animals are kept for any purpose, to keep such barn, stables, and other places above mentioned or allow the same to become filthy, noisome, or unsanitary.

"Section 2.—That every person owning, operating, or controlling the use of any building or part of a building or any place within the city, who has one

or more horses, mules, cows, or other like animals kept in the same, shall maintain in connection therewith a bin or pit in which the manure from said animals shall be placed, pending removal; said bin or pit to be provided with water-tight cover of sufficient strength and close fitting to prevent the ingress and egress of flies; said bin or pit shall be located within lot lines at a point most removed from any dwelling, or other structure, owned or occupied by others than the owner of the premises above mentioned, and shall likewise be placed at a point most remote, on the premises, from any street or avenue.

"Section 3.—It shall be unlawful for any person to hold such manure on said premises for a period longer than fourteen days; provided, however, that any of said persons may use said manure on their premises for the purpose of enriching their own ground, or for any other use to which manure can properly be put, provided said manure be scattered and spread on the ground, so that the same may not become offensive or unsanitary; and, provided further, that any person, firm, or corporation may remove manure from bins, pits, or other places where deposited as required by this ordinance, for any purpose, where such manure has not become offensive or unsanitary.

"Section 4.—That any person, firm, or corporation owning any stock, as enumerated in Section 2 of this ordinance, may, by paying annually to the City of Columbus the sum of $3.00 for one head of stock owned by them, or $5.00 for two head and $1.00 for each and every head of stock over and above two head owned by them, be relieved from removing said manure from the bin or pit in which the same is required to be deposited, said City, on payment of such charge, undertaking to do the work of removing the same.

"Section 5.—That any person, firm, or corporation owning any stock, as enumerated in Section 2 of this ordinance, shall, by paying to the Treasurer of the City of Columbus the sum or sums required in Section 4 of this ordinance, receive a receipt card, signed by the Auditor of said City, which card shall be posted in a conspicuous place, on or within any of said barns, stables, sheds, stalls or similar places wherein animals are kept, as provided for in Section 1, and the Auditor of said City shall be required to notify the Director of Public Service that such person, firm, or corporation has deposited the required sum, provided, however, that should any person, firm, or corporation mentioned in the foregoing sections of this ordinance fail to procure such receipt card, and fail after a period of fourteen days to remove such manure, as required in Section 3 of this ordinance, may, by paying to the City of Columbus the sum of $2.00 per load or part thereof, for each and every load or part thereof, have the same removed by the said City. The Director of Public Service shall make rules and regulations for the collection, removal, and disposition of manure.

"Section 6.—That it shall be the duty of the sanitary inspectors to inspect such bins or pits and require the same to be emptied as required by the terms of this ordinance. All wagons used for the removal of said manure shall be so constructed as to prevent the same from being dropped or spilled along the streets or public places within the city.

"Section 7.—Any person or persons violating the provisions of this ordinance, shall, on conviction thereof, be fined not less than $5.00 or more than $50.00 for the first offense, and for each subsequent offense not less than $50.00

or more than $200.00. This ordinance is hereby declared to be an emergency measure.

"Section 8.—That all ordinances and parts of ordinances in conflict with this ordinance be and the same are hereby repealed.

"Section 9.—That this ordinance shall take effect and be in force from and after the earliest period allowed by law.

"Passed February 12, 1912."

The practical effect of this ordinance has been to remove many old nuisances.

2. Equipment.—Where manure is collected by stable users or farmers, special equipment for the service is not possible. Wagons used for regular stable or farm work will be used only once or twice a week for the removal of manure. The same practice would apply to the use of city teams which work in other parts of the service most of the time.

If the disposal is on the separate plan, stable manure should not be removed with any rubbish or garbage, but should await collection in separate masonry pits which are drained and ventilated. Where the quantities are large, they should be stored in large vaults and collected specially.

Large wagons, holding from 5 to 8 cu. yd., and used continuously by the city, are desirable. They should be covered, in order to prevent unsightliness when passing through the streets.

C. FINAL DISPOSAL

There are three methods for the final disposal of stable refuse. One, spreading it on the soil and used as fertilizer; another, dumping it on waste land for land-filling; and a third, destroying it by incineration.

1. Fertilizer.—The best method of disposing of manure is to use it as a fertilizer; and the greater bulk of it, in the cities of Europe and the United States, is utilized in this way. A fertilizer, broadly defined, is anything that will increase the productive yield of the soil to which it is added. The valuable constituents of fertilizers are nitrogen, phosphoric acid, and potash. As manure contains these elements, it adds to the productivity of land, and is classed as a natural fertilizer. It is possible to convert stable manure into a better fertilizer, for the purpose of better disposition. Even if this is done without profit, it may be in some cities the least expensive method of final disposal.

An analysis of fresh manure, given in Table 170 shows that it contains 0.64% of ammonia, 0.33% of phosphoric acid, and 0.67% of

potash. In order that the fertilizing elements may be made available for plant food, they must be in soluble form. Of the total organic matter in fresh manure, a little more than 7% is soluble, and, of the inorganic matter, about 4½% is soluble. Table 172, taken from page 55 of "Talks on Manure," by Harris, shows an analysis of the manure before and after it had fermented. The fermentation adds to its value as a fertilizer, by changing some of the insoluble compounds into soluble form. According to the analysis given, the percentage of soluble organic matter increased during three months from 7.33% to 12.79%, and the soluble inorganic matter from 4.55% to 9.84%, or more than double.

TABLE 172.—EFFECT OF STORAGE AND EXPOSURE ON THE COMPOSITION OF MANURE, CALCULATED ON A DRY BASIS

Item	Date of Sampling				
	Fresh when put up,	After fermentation			
	November 3d	February 14th	April 30th	August 23d	November 15th
Soluble matter:					
Organic	7.33	12.79	12.54	12.04	10.65
Inorganic	4.55	9.84	8.39	8.03	7.27
Insoluble matter:					
Organic	76.15	61.12	56.49	49.77	42.35
Inorganic	11.97	16.25	22.58	30.16	39.73
Totals	100.00	100.00	100.00	100.00	100.00

Manure should be properly fermented, if the best results are to be secured. The fermenting pile should be placed on an impervious bottom, sloping down toward the center. This prevents the soluble compounds from being washed away during rain storms; yet, the fermenting manure should not be allowed to become too dry. As the process of fermentation is the oxidizing or burning up of the dry organic contents, it should not proceed too actively or too slowly, and there should be sufficient moisture to absorb the portions of the volatile organic matters which are driven off by the fermentation. Experiments have shown that fermenting manure exposed to the weather does not become too wet, and that rain will not harm it.

In the process of fermentation, the organic nitrogen is first changed into ammonia. If the ammonia escapes from the pile, there is a clear loss in fertilizing value. Therefore, the pile should be carefully thatched or covered with canvas, and the heap should not be turned over more frequently than necessary. It has been observed that the fermentation of manure destroys the seeds of weeds contained in the original bedding. The effect of ammonia on fly maggots does not seem to have been determined. In the fermenting mass the using up of the oxygen and the formation of various volatile compounds may create an environment not suitable for the rapid development of flies. If this should be the case, it would be an added and important reason for allowing fermentation.

The question of how the fermentation of manure and its subsequent distribution to the farmers should be effected is rather difficult to answer at this time. It would seem, however, as though city officials, possibly in connection with poor farms or county institutions, could practice composting as a source of revenue. Whether the results show a gain or a deficit, the benefit in securing prompt and effective service during the summer would be sufficient warrant for the work. Some manure might probably be handled in this way by the Park Departments.

2. Land-fill.—Making land by dumping stable refuse, as has been practiced in some western cities, is objectionable chiefly as it is favorable to fly breeding, although it may be less costly than better methods. Unless it receives a good earth cover—and, when the quantity thus disposed of is large, this has often been insufficient—offensive odors will arise. As the manure gradually decomposes, the filling settles, which makes the land worthless for improvements until after a long term of years.

Although this method of disposal may be justified in some cases for stringent financial reasons, it should be considered as but temporary, and a better one substituted as soon as possible.

3. Incineration.—Manure has been disposed of in a few instances by burning it in large quantities, but this cannot generally be regarded as a satisfactory solution. In Milwaukee, the Health Department has had so much difficulty in forcing its prompt removal from stables, because of the lack of a proper point of delivery and discharge, that it was insisted that provision should be made at the incinerator for burning it. This was done, but, as it was not a satisfactory fuel, it became a burden on the incinerator. Its large bulk, its mixture with much mineral street dirt, and the difficulty of forcing air through it, on account of its matting, all tended to reduce the total capacity of the plant.

From the point of view of economy, burning manure at Milwaukee is not advantageous. However, for sanitary reasons, it has some merits, as it provides an effective, easy, and always ready means of disposal. It also makes it easier for the sanitary inspectors to insist on prompt and frequent removals. It completely destroys the manure, with the contained maggots, preventing the production of flies, which might proceed if it were taken to a farm and not promptly turned into the soil. In any case, capacity in the local incinerator for at least a portion of it is advisable.

In Kansas City some manure has been burned recently in shallow ridges on the ground in the open. The ashes are recovered and sold for their content of potash.

D. RESULTS IN PRACTICE

Experience with the removal of manure in American cities does not indicate any special line of progress, but rather a need for better development. Dr. P. M. Hall, when Health Commissioner of Minneapolis, published some notes on the practice in various cities, from which the following items are taken:

1. Minneapolis.—The manure is disposed of during the winter by the voluntary collection of market gardeners and farmers, but, as soon as spring work opens up, the collection in the city is sadly neglected. Several years ago an ordinance was passed, permitting private collectors between April 1st and October 1st each year to collect it and charge the horse owner a fee of 50 cents per month per animal. All the known private haulers in the city, together with the regular scavenger companies, were notified and furnished with copies of the ordinance, and for the first year the collecting was fairly well done.

The one great difficulty to contend with was that the collectors found no sale for it, as the farmers and market gardeners did not want it at that time of the year, and objection was made to its being stored anywhere. The ordinance had the usual requirements of keeping manure in a water-tight box; that it should be collected at least once a week between April 1st and October 1st; that those hauling it should be careful that there should be no spilling on the street, etc. The ordinance is still in existence, and has not been superseded by a new one. It is indifferently enforced.

2. Washington.—The law in force in the District of Columbia requires every person owning or occupying a building, within the more densely populated parts of the District, where one or more horses, mules, or cows are kept, to maintain in connection therewith a bin or pit for the reception of manure, pending its removal from the premises. These bins or pits must be fly-tight and water-tight. The manure must be removed from the premises twice a week between June 1st and October 31st, and at least once a week between November 1st and May 31st. The manure, when transported over the high-

ways of the densely populated parts of the District, must be in tight vehicles which, if not enclosed, must be covered so as to prevent it from dropping on the streets. The method of collecting from these bins or pits is not uniform, it being the duty of the owner of the stable to arrange for its removal. There are in the District six or more companies that deal in manure. Wagons are maintained by them, in some instances exclusively for its collection; in others, they are used also in similar branches of their business. These wagons collect from the bins or pits, and convey the manure either to the railroad stations for shipment or directly to the property of the person purchasing it. In many instances these companies pay to those in charge of the stables a small sum for the privilege of obtaining the manure. Some of the farmers residing within the immediate vicinity of Washington collect it from the stables of the city during certain months of the year. This service, however, has proved unsatisfactory in that the farmers do not call for it during the growing season, because of the demand for their teams in other work on the farm. The manure from the stables under the control of the municipality is used on the grounds of the municipal workhouse and almshouse and on some of the city's parks.

3. Toronto.—The City has contracts with four different companies for the removal of all manure, which has to be taken from all premises at least once every week. The Department of Health requires manure to be kept in water-tight, fly-proof bins or receptacles. If these bins extend below the level of the ground, they are required to be constructed of concrete, and connected by a trap to the sewer on the street.

The companies make a nominal charge to the different stables, etc., the Department of Health insisting on regular removal. There is, therefore, no cost to the Department in connection with the removal of this portion of the city's waste.

4. Jersey City.—All manure is carted away by private contractors at no cost to the City, its storage not being allowed in the city. Most of it is sold to farmers for fertilizing purposes.

5. Richmond.—According to statements of the Health Commissioner, Dr. E. C. Levy, more trouble is encountered in Richmond, in connection with the removal of manure from the small private stables than from the large livery stables. The latter are able to make contracts for its removal throughout the year, but the small stable owner is not able to do so, and finds the greatest difficulty in having it taken away during the summer—the very time when its removal is most important.

Methods of dealing with this problem have been considered. In the opinion of Dr. Levy, the City itself should be prepared to remove manure from stables when the owner or occupant fails to do so in accordance with the law. Every horse owner, of course, should be allowed to sell it if he can, and in doing so comply with the law; otherwise, it should be regarded as a nuisance, and the City, it would seem, would then have a perfect right to remove it without compensating the owner, and, indeed, going further and charging the owner for the service, if this is found necessary.

6. Rochester.—The City does not collect or dispose of manure. It is considered a by-product which the stable keepers sell to the local farmers. Dr.

Joseph Roby writes: " I cannot see that it has any particular bearing on the public health, except so far as the manure pits are breeders of flies."

7. Denver.—The present method of manure disposal in Denver consists of transferring it to the city dumps, where it is held during the summer and in the spring sold to market gardeners. The chief sanitary inspector of the department writes that the service lacks much of being satisfactory, and that the methods will probably be improved in the near future.

8. Columbus.—Columbus collects manure from any stable within the city limits on payment of a moderate fee. It is disposed of by sale to farmers or other parties desiring to use it as fertilizer. All stable owners in the city are required to keep it in tight boxes and have it removed at regular intervals, whether by the City or private individuals. The charge made to the stable owner is nominal, and does not meet the entire cost of collection, which is about $12,000 per year. " This system has not been in effect any great length of time," writes the Acting Superintendent of Sanitation, F. M. Hoffman, " so we are unable to give any exact observation on its bearing toward public health, but will say that a great many old nuisances have been cleaned up thereby."

The City has also been delivering manure to land which is owned by the City and is being cultivated by workhouse prisoners during the period when there is the least demand for it elsewhere.

Quoting from " Reports on Collection and Disposal of Refuse and Garbage," of the Columbus Department of Public Service:

" Previous to April 1, 1912, the City collected free of charge all the manure from the different stables. On February 13, 1912, the Council passed Ordinance No. 26245 to regulate the collection of manure. This ordinance provided that, if any person or persons desired to have the manure removed from stable or stables, they would be compelled to take out a permit for such service at a yearly charge of $3 for one horse; $5 for two, and $1 for each additional horse. After the ordinance became a law, the Department commenced to notify the public that from and after April 1, 1912, no manure would be removed without payment of the fee. Since that date the owners of 976 horses have paid $1665 to the City Treasurer.

" The sale of manure is a perplexing problem. Between September 1st and June 1st, the demand for manure is greatly in excess of the supply, and the City could sell three or four times as much as is collected. From June 1st to September 1st, there is practically no demand, as the farmers cannot handle it during that time. There should be some method devised to store the manure during this period, when by order of the Board of Health we are prohibited from holding it within the city awaiting the marketing period. The manure we were ordered to dispose of at once this summer had to be given away at a loss of $750 to the City.

" The price received is $1.50 for a wagon load; $7.50 for a 30-ton car; $10 for a 40-ton; and $12.50 for a 50-ton car. These prices are based on coal cars of these capacities, and do not mean that these cars hold that much manure. The sale of manure collected (130 car loads and the remainder by the wagon load) gave the City a revenue of $4,106.85.

"The collection of manure is made under the following rules: Whenever a person or persons pay to the City Treasurer the ordinance charge for manure collection, the department is notified. The name, address, permit number, and number of horses are recorded in alphabetical order.

"Each driver (four being used in the collection) is given a separate list of barns, and every evening reports the places collected from. The date of each collection is noted in the office record. Thus, the department is always able to show the date of every collection from each place, and to see that collections are made as frequently as necessary."

A detailed statement of the receipts from and the cost of collection and the sale of manure collected, follows:

Total number of loads collected (year 1912)	3,720
Total number of tons	7,440
Total number of yards	18,600
Cost of teams and labor	$7,625.58
Superintendent, inspection	318.82
Repairs and miscellaneous	205.70
Cash paid to City Treasurer	4,081.35
Cash on hand December 31, 1912	15.00
Open accounts on book for year 1912	10.50
Sale of manure permits	1,664.00
Total	$5,770.58
Total operating cost	8,150.10
Total receipts	5,770.85
Net cost	$2,379.25
Cost of collection per load	$2.19
Cost of collection per load, receipts deducted	0.64
Cost of collection per ton	1.10
Cost of collection per ton, receipts deducted	0.32

9. Canada.—In Winnipeg, Edmonton, and other Canadian cities, as there is no demand for manure as a fertilizer, it is incinerated, but how successfully and at what cost we are at present unable to state. Table 173 shows the quantities collected in Winnipeg during the years 1911 to 1914, inclusive.

E. SUMMARY AND CONCLUSIONS

The present status of stable treatment of manure in the cities and towns of America is not wholly satisfactory, because not enough attention is given to the prevention of fly breeding. All reasonable methods of accomplishing the elimination of flies should be required of stable owners. We have given extended information on this

subject. Instead of being fairly regular, the removal of manure is irregular, particularly during the critical summer season. More suitable, and in hot weather, more frequent, collections should be made.

TABLE 173.—MANURE COLLECTION IN WINNIPEG, MAN.
QUANTITIES IN TONS

Data from Annual Reports, Dept. of Public Health.

Year	1911	1912	1913	1914
Population	151,958	166,553	184,730	204,000
January	88.70	115.22	91.85	180.98
February	102.89	110.41	132.30	178.70
March	115.90	121.12	152.27	211.50
April	75.83	114.48	142.63	209.33
May	110.23	116.73	144.72	192.17
June	82.89	116.84	125.70	229.55
July	81.91	105.80	150.40	229.57
August	90.10	125.00	153.30	192.50
September	87.62	110.02	157.75	188.48
October	103.04	146.25	157.10	209.55
November	105.25	141.10	142.57	209.70
December	120.43	118.78	155.15	235.05
Totals	1164.79	1441.75	1705.74	2467.08
Tons per 1000 population per year	7.67	8.65	9.24	12.08
Pounds per 1000 population per day	49.5	55.8	59.6	78.0

Experience favors a municipal service, to supplement the private endeavor by a close inspection and supervision, but in both cases the service should be paid for by the corporations or persons on whose premises the manure is produced. Keeping horses is a private matter, and is similar to conducting a business.

The method of final disposal depends entirely on local conditions. Utilization as a fertilizer and destruction by burning are the two best methods. When properly mixed with ashes, manure may be dumped, if kept well covered to prevent fly breeding.

CHAPTER XV

STREET REFUSE

Street sweepings consist of the refuse which accumulates on the surfaces of streets, roads, alleys, walks, and other areas. When paved with stone, roadways have been swept and cleaned since Greek and Roman civilization. Unpaved roads, however, were hardly ever cleaned. They were repaired, or the surfaces reshaped, whenever considered desirable. In many cases rubbish was thrown on them and leveled, so that earth roads were gradually raised, until, after centuries, they were 6 ft. or more above the original level, as disclosed by excavations in Italy and Central Europe. Rome and Prague, not fifty years ago, gave this evidence.

The problem of the disposal of street sweepings did not arise seriously until modern times, when street paving became more general, and the removal of city refuse more desirable. Short hauls permitted first a simple dumping at suitable places near the outskirts of a city; but the fact that sweepings from paved streets contained a large quantity of manure, and that they were increasing in volume, suggested their utilization for agricultural purposes. Such disposal prevails at this day in many cities of Europe. In quite recent years, the quantity of manure gathered from streets, however, has been decreasing, with the substitution of motor trucks and automobiles for horse-drawn vehicles; and a still further decrease is to be expected.

It is not our intention to give here more than the briefest outline of street cleaning, as this subject alone would require a volume for thorough discussion. For the present purpose we shall assume that the streets have been cleaned, and that the sweepings, litter, dust, and snow have been gathered at suitable points on the street, where they can be collected and removed for final disposal.

Clean streets should be an object of city pride. They greatly improve, not only the appearance of a city along its highways, but also the interior conditions of the houses, by preventing or lessening dust that is blown in and mud that may be tracked in from the street. Efficient street cleaning also affects the inhabitants themselves, par-

ticularly the poorer classes, as to their appearance, pride, and even health, which was attested by the late Col. George E. Waring, Jr., Street Cleaning Commissioner of New York City, and is demonstrated by a number of manufacturing towns in the Essen District of Germany. Visitors are influenced by the appearance of the street surfaces almost as much as by the buildings.

The principal methods of street cleaning now in use are machine sweeping, hand sweeping, and street flushing by hose and by machines. Street sprinkling is not a cleaning method, but is used merely to lay the dust. In recent years much attention has been given to street flushing, as this is the best means of removing the fine dust and the bacteria that are contained in it. The New York Street Cleaning Commission found that flushing caused a reduction of bacteria in the air above the pavement of from 239 to 85 colonies. European evidence points to similar reductions accomplished by flushing.

In order to secure a satisfactory result with these methods, it is necessary to have a competent organization of faithful and efficient men. In those cities which have the best trained corps, permanently engaged, independent of political appointments, rewarded for good or better work, and taking pride therein, we find the cleanest streets, provided the pavements are modern, and have been well designed and evenly laid, so as to present a regular and smooth surface. Pavements must have these characteristics if clean streets are continuously to be maintained.

The best streets for heavy traffic are paved with stone blocks, but in order that such pavements may be well cleaned at the least expense, the blocks must be smoothly dressed and set with narrow joints, between $\frac{1}{4}$ and $\frac{1}{2}$ in. in width. Such pavements are found in many European cities, the best being those made with blocks of Penmaenmaur granite in Liverpool. The best pavements for general city conditions on light grades are made of sheet or block asphalt, of hard and tough bricks, or of wood or concrete. Such pavements are smooth, so that cleaning is easy, and can be thoroughly done both by sweeping and by flushing. Less hard and less smooth pavements produce more dust by attrition. The ordinary roughly dressed stone blocks with 1-in. joints, cobble and rubble pavements, are almost impossible to keep free from fine dust raised by the wind.

A. MATERIALS

The materials to be removed are a mixture of freshly deposited pieces, which may be picked up by hand and put into can or bag carriers, fine particles, which must be swept into piles for loading by

shovel, and still finer particles, ground to dust and likely to be blown about by the wind; the latter are best removed by flushing.

In order to lessen the work of removing the materials which make up street refuse, it is imperative to keep them as much under control as possible. We cannot control dust, smoke, horse droppings, dirt dropped from vehicles, mud dragged on from unpaved roads and alleys, and falling leaves in the autumn; but we can prevent, by regulations and their enforcement, the careless scattering of refuse on the streets, by providing special cans for the reception of much of it, thus facilitating the collection and removal.

The coarse and fine materials, the litter and dust, come from various sources:

First, the droppings from horses and smaller animals, similar to stable refuse (Chapter XIV). This material may become offensive by being ground into dust, raised into the air by the wind, and blown into the buildings.

Second, miscellaneous litter thrown upon the streets, by pedestrians, from sidewalks and buildings, and dropped from rubbish and service wagons, and push carts. It is chiefly paper, pieces of wood, fruit skins, earth, sand, stones, etc.

Third, material dragged by wheels from unpaved to paved streets.

Fourth, building material, during the construction of buildings, street and sewer repairs, and temporary storage of such materials, etc.

Fifth, leaves, and sweepings from buildings and sidewalks.

Sixth, snow and ice.

Of these materials, one part consists of dust either deposited from the air or originating on the streets through attrition and disintegration; another part consists of the larger and heavier materials; and a third material is snow and ice.

(*a*) Dust is the most objectionable part of street refuse, as it enters houses and settles on the floors and furniture, and on goods in stores. It can be settled and compacted on the streets temporarily by sprinkling, and then removed by brooming to piles to await collection by carts; or, it can be flushed into the sewers by the use of hose or water carts. We are here interested in removing only the former, as the entrance into the sewers obviates the necessity for collection by vehicle.

Table 174 gives an analysis of street dust from the down-town district of Chicago, taken from data reported by Richard T. Fox in 1915. The greatest quantity of dust appears between the rails of street railroads. On the streets of residential districts, generally, a greater quantity of manure was found than in other districts.

TABLE 174.—Quantity and Composition of Street Dust in the Down-town District of Chicago

Reported by Richard T. Fox, 1915.

Item	Pounds per 1000 Square Yards		
	Sidewalk	Roadway	Street railway right of way
Carbon and organic matter	0.67	3.00	25.00
Silica	0.96	4.70	50.50
Calcium carbonate	0.20	0.60	6.00
Magnesium carbonate	0.02	0.30	2.30
Iron	0.11	0.25	3.00
Undetermined	0.04	0.15	0.20
Totals	2.00	9.00	88.00

Fox estimated that the daily quantity of street dust in Chicago varied from 1 to 10 cu. ft. or more, on 1000 sq. ft. of pavement.

Extensive observations on street dust quantities were made by Dr. Renk in the outskirts of Dresden, in 1910, to determine the quantity of dust in the air 2.5 m. (8.2 ft.) above the street surface. The quantities of dust found varied from 0 to 1 mg. in 1 cu. m. of air. About 0.5 mg. in 1 cu. m. was considered to be the allowable limit, after which dust became unpleasant.

In 1907 the New York Commission on Street Cleaning made some special observations on street dust. Table 175 is taken from the report of that Commission.

The samples in Table 176, taken after regular cleaning, show a high percentage of ash, because there would be in them less combustible waste, such as horse droppings, paper, and wood than in the general street dirt before the cleaning.

Dust is best removed by water flushing. If swept up, sometimes even after a slight sprinkling, it produces objectionable conditions in the air above. Flushing, to be most effective, necessitates smooth pavements.

(*b*) The larger and heavier materials vary greatly in size and quantity. They reach a minimum during the winter and a maximum in the spring, when the accumulations of the winter are being removed. The material consists mostly of rubbish, which is chiefly general litter, such as paper, straw, boxes, fruit skins, and pieces of wood,

TABLE 175.—QUANTITY OF STREET DIRT (MOSTLY DUST) REMAINING ON STREET SURFACES AFTER REGULAR STREET CLEANING IN NEW YORK (MANHATTAN).

OBSERVATION BY COMMISSION ON STREET CLEANING, 1907

Computed quantities per 1000 sq. yd.

Pavement	Travel	How swept	Volume, in cubic feet	Weight, in pounds	Weight per cubic foot
Asphalt	Light	Hand	0.092	3.63	39.5
Asphalt	Medium	Hand	0.206	13.65	66.2
Block asphalt	Light	Machine	0.573	37.75	65.9
Block asphalt	Light	Hand	0.590	38.70	65.6
Asphalt	Heavy	Hand	0.648	30.77	47.5
Asphalt	Light	Machine	0.830	35.83	43.2
Granite block	Heavy	Hand	4.802	191.25	39.8
Wood block	Heavy	Hand	1.476	30.35	20.6
Averages	....	....	1.152	47.74	48.5

ANALYSIS OF AVERAGE MIXTURE OF THE MATERIAL IN TABLE 175.

Moisture (air-dried)	2.35%
Volatile combustible matter	17.67%
Fixed carbon	5.84%
Ash	74.14%
	100.00%

including also earth and wasted material from building operations. In dry weather, also, this street dirt becomes dusty, in wet weather muddy.

Leaves sometimes form an important part of the sweepings, as their quantity may be quite large on streets lined with trees. The time when their removal is required is generally confined to about two months in the autumn. They are very light and therefore easily blown about.

It is found expedient in many cities to add the cleanings from street catch-basins to the street sweepings, and these are together shoveled into piles and loaded into the street-cleaning wagons.

The larger materials contain less moisture than manure, unless they are collected in rainy weather. They are also less likely to create nuisances, because more resistant to decomposition. In 1911 the specific gravity of Berlin's street sweepings from asphalt pavements in wet weather, and when strewn with some sand, was 1.8. In dry weather and with no sand, it was from 0.6 to 0.8.

TABLE 176.—ANALYSES OF STREET SWEEPINGS MADE BY COMMISSION ON STREET CLEANING (1907) IN MANHATTAN, NEW YORK

Pavement	Travel	Weather	Percentages			
			Moisture, air-dried	Volatile combustible	Fixed carbon	Ash
Sheet asphalt. . .	Light	Dry	3.56	54.03	0.15	42.26
Sheet asphalt. . .	Heavy	Dry	2.93	64.72	11.96	20.39
Wood block.	Heavy	Rainy	2.56	54.31	13.36	29.77

INCLUDED IN THE SAMPLES ANALYZED ARE THE FOLLOWING MATERIALS:

	Phosphorus pentoxide	Potassium oxide	Total nitrogen	Water-soluble phosphorus pentoxide
Sheet asphalt.	0.79	0.73	1.00	0.34
Sheet asphalt.	0.95	0.86	0.90	0.50
Wood block.	0.70	0.80	0.74	0.16

Occasionally, street refuse materials have been analyzed, measured, and weighed. Some of the results are given in Tables 175 and 176.

Table 177 contains information from several cities concerning the composition of street sweepings and their value as fertilizers. It was compiled, and enlarged with some original analyses, by the New York Street Cleaning Commission of 1907.

The sweepings from a street subject to both heavy and light traffic show, when incinerated, a much higher percentage of ash for light than for heavy traffic, because there would be fewer horse droppings and less other combustible waste, such as paper, wood, etc.

Table 178, made up from figures given in the Report of the Commission on Street Cleaning, of New York City, 1907, gives the quantities of street sweepings in the five boroughs of the city in 1904, 1905, and 1906, from which the pounds per capita per annum have been deduced. See also Table 25 in Chapter I.

Table 179 shows the quantity of material collected by the regular sweeping service of New York City in 1907.

TABLE 177.—COMPOSITION OF STREET SWEEPINGS AND

Figures are given

City	Year.	Source of Material, Conditions, etc.	Kind of pavement from which collected	COMPO Moisture	Organic matter
Washington.	1898	Street sweepings from dump, composite sample, several months old.	Asphalt	45.7	16.3
Washington.	1898	Street sweepings from dump, mostly manure, 6 to 8 months old....	Asphalt	28.7	14.5
Washington.	1898	Fresh hand sweepings taken from dump, material mostly manure...	Asphalt	39.5	28.9
Cincinnati..	1889	Average fresh sweepings taken from Race Street....................	Asphalt	46.11	26.9
Berlin......	....	Street sweepings.................	Asphalt	39.89	22.44
New York..	1896	From New York Streets..........	....	32.88	......
New York..	1896	From New York streets...........	....	21.68	......
New York..	1907	Street sweepings collected by Commission on 89th Street...........	Asphalt	[2] 3.56	[3] 54.18
New York..	1907	Street sweepings collected by Commission on Warren Street........	Woodblock	[2, 4] 2.56	[3] 67.67
New York..	1907	Street sweepings collected by Commission on Broadway between 37th and 40th Streets................	Asphalt	[2] 2.93	[3] 76.68
....	....	Pure horse manure...............	....	11.24	......
....	....	Stable manure..................	....	73.27	......
....	....	Well-kept mixed stable manure.....	....	......	......

[1] Uncertain whether reported analyses are based on included moisture or not.
[2] Air dried.

A sample, covering four weeks of sweepings in Trenton, gave the following analysis:*

Nitrogen..................................	0.18
Phosphoric acid............................	0.30
Potash....................................	0.19

The analysis, by Petermann and Richard, of the sweepings in Brussels, Belgium, in 1900, in parts per 1000, is:

Nitrogen..............................	4.72
Carbon, oxygen, and hydrogen............	307.28
Organic matter.........................	312.00
Phosphoric acid.........................	5.30
Potash................................	2.30
Iron, lime, and aluminum................	85.70
Sand..................................	594.70
	1000.00

* New Jersey Agricultural Experiment Station, 1895.

MANURE, ORGANIC MATTER, AND VALUE AS FERTILIZER
in percentages.

SITION.		ANALYSIS FOR FERTILIZER.						Authority and Remarks
		As Reported			Reduced to Dry Material			
In-organic matter	Or-ganic in dry mate-rial	Nitro-gen	Phos-phoric acid	Potash	Nitro-gen	Phos-phoric acid	Potash	
38.0	30.0	0.39	0.08	0.09	0.72	0.15	0.17	Bul. No. 55, U. S. Dept. Ag.
56.8	20.4	0.32	0.08	0.11	0.45	0.11	0.15	" " "
31.6	47.7	0.55	0.10	0.37	0.91	0.17	0.61	" " "
27.0	50.0	0.91	1.31	0.33	0.91	1.31	0.33	F. C. Wallace
37.67	37.2	0.48	0.45	0.37	[1]....	....	....	Vogel. See Bul. No. 55
....	....	0.29	0.38	0.37	0.43	0.57	0.55	Van Slyke, N. Y. Agricultural Experiment Sta.
....	....	0.21	0.32	0.32	0.27	0.41	0.34	
42.26	[3]56.2	1.00	0.79	0 73	1.04	0.82	076	Lederle Laboratories
29.77	[3]69.4	0.74	0.70	0.80	0.76	0.72	0.82	" "
20.39	[3]79.0	0.90	0.95	0.86	0.93	0.98	0.89	" "
....	....	0.74	1.45	2.82	[1]0.83	1.63	3.18	Mass. Agr. Exp. Sta.
....	....	0.50	0.30	0.60	[1]1.87	1.12	2.24	Year Book, 1884, Agr. Dept.
....	....	0.50	0.25	0.50	....	....	....	Van Slyke, N. Y., Agricultural Experiment Station

[3] Reported as volatile combustible matter and fixed carbon.
[4] Sixty per cent. water in original sample collected on a wet day.

An analysis of the street sweepings from asphalt paved streets in Berlin in 1892 * gave the following composition:

Moisture	39.89%
Ash	37.67%
Organic matter	22.44%
	100.00%
Total nitrogen	0.479%
Ammoniacal nitrogen	0.004%
Phosphoric acid	0.452%
Potash	0.370%
Lime	1.891%
Magnesia	0.347%

In Hamburg the weight of street sweepings varied, according to the contained moisture, from 750 to 1100 kg. per cu. m. (1264 to

* Vogel, in *Mittheilungen der deutschen Landwirtschafts Gesellschaft*, 1892.

TABLE 178.—QUANTITIES OF STREET SWEEPINGS COLLECTED IN THE FIVE BOROUGHS OF NEW YORK CITY

(Report of Commission on Street Cleaning and Waste Disposal, New York City, 1907, pages 12–14)

Year	Population	Cubic yards	Tons	Average weight per cubic yard, in pounds	Pounds per capita per annum
MANHATTAN					
1904	2,060,041	629,506	319,789	1016 [1]	310
1905	2,112,528	659,794	335,175		317
1906	2,165,015	703,382	357,318		330
THE BRONX					
1904	301,161	55,020	27,950	1016 [1]	186
1905	362,324	60,414	30,690		188
1906	351,487	60,904	30,939		176
BROOKLYN					
1904	1,349,129	316,760	121,953	769	181
1905	1,394,766	314,054	120,911		173
1906	1,440,403	313,516	120,704		168
QUEENS					
1904	199,359	......	......	1016 [1]	......
1905	210,949	55,120	21,194		201
1906	222,539	70,934	27,274		245
RICHMOND					
1904	74,969	......	......	1800 [1]	......
1905	76,956	33,728	30,355		789
1906	78,943	35,262	31,736		804

[1] It is most probable that the average weight was less for Manhattan, and correspondingly greater for the suburban boroughs, because there was more clay and sand in the sweepings. In Richmond, where the length of earth roads was proportionately greater, the high average may be explained for the same reason.

TABLE 179.—MATERIAL COLLECTED FROM REGULAR STREET SWEEPINGS IN MANHATTAN, NEW YORK. COMMISSION ON STREET CLEANING AND WASTE DISPOSAL (1907)

Kind of pavement	Condition of repair	Weather		Weight per cubic foot	Quantity per 1000 Sq. Yd.		Number of horses	Pounds per 1000 sq. yd. per 1000 horses
		Day of observation	Preceding day		Volume, in cubic feet	Weight, in pounds		
Asphalt	Very good	Fair	Fair	44.8	1.56	70	236	208
Asphalt	Good	Showery	Fair	34.2	6.95	237.6	6096	39
Asphalt	Good	Fair	Fair	35.3	4.82	170.1	4704	36
Asphalt	Good	Fair	Showery	32.1	8.33	267.4	8064	33
Asphalt	Good	Some rain	Rainy	48.8	8.23	385.2	4416	87
Granite block	Fair	Some rain	Rainy	39.5	14.05	555.0	5280	105
Granite block	Fair	Fair	One shower	36.9	12.26	451.4	6048	75
Wood block	Good	Fair	Rain	46.6	14.50	675.7	4032	167
Wood block	Good	Fair	Fair	34.9	16.43	573.4	5473	105

1854 lb. per cubic yard). The quantity varied with the pavement and the traffic. After a heavy rainstorm there was almost none, because nearly all the material goes into the sewers. In 1903 the annual cost of collecting and dumping the sweepings was 1.14 mark per cubic meter (21 cents per cubic yard), and 0.22 mark ($5\frac{1}{4}$ cents) per inhabitant.

In Dresden the cost of street cleaning per square yard of cleaned street surface per annum in 1903 was, on asphalt pavements about 4 cents, on stone pavements about 5 cents, and on macadam streets about 2 cents.

From measurements made in recent years, the following cities removed approximately the stated quantities of street dirt from 1 sq. m.

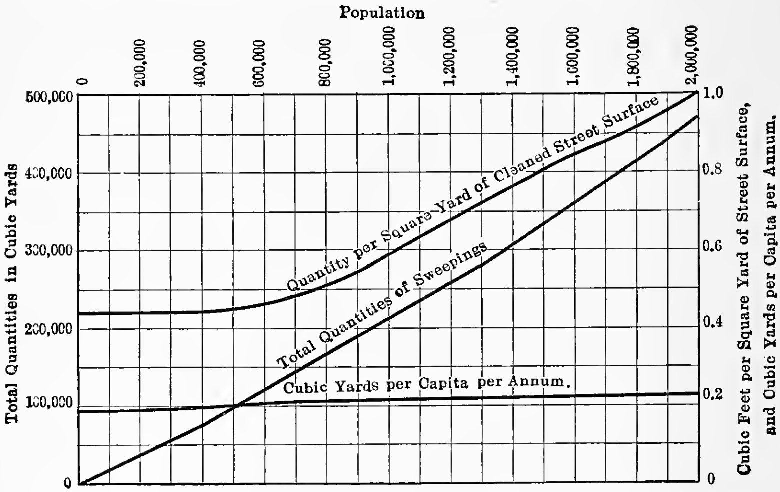


FIG. 126.—Approximate Annual Average Quantities of Street Sweepings in European Cities.

of average pavement per annum: Berlin, 0.025 cu. m.; Hamburg, 0.022 cu. m.; Altona, 0.017 cu. m.; and Kiel, 0.013 cu. m. The quantities reduced per inhabitant give: For Berlin, 0.14 cu. m.; for Hamburg, 0.20 cu. m.; for Altona, 0.09 cu. m.; and for Kiel, 0.09 cu. m.

Fig. 126 gives an approximate idea of the annual average quantities of street sweepings in European cities of different sizes, for populations up to 2,000,000. It shows the total quantities removed, and the quantities per capita and per square yard of cleaned street surface. It was compiled by Franz Niedner, City Engineer of Dresden, Germany, in 1911.

(*c*) *Snow,* when considered to be a part of municipal refuse, is that which falls on the roadways and is thrown on them from the side-

walks and private premises. It includes the slush and ice on the streets.

When the quantity of snow that has fallen is large enough to interfere with the movement of pedestrians on the sidewalks and vehicles on the roadways, it is necessary to remove it. It is usual to clear the snow from sidewalks into the streets, as this is necessary for the comfort of pedestrians. Vehicles can readily use a roadway until it has from 2 to 3 in. of fresh snow on it. When the quantity is greater, sleighs are substituted in the smaller cities and in the suburbs of the larger ones. Only in those streets having the principal travel, and the main streets of the larger cities, is the snow removed artificially by the respective city departments.

Contract removal, if paid for by quantity, requires careful measurements. It is extremely difficult, if not impossible, to determine the exact quantity of snow removed. One method is to measure with a gage the depth of snow that has fallen and use it for the area of the street on which it has fallen. However, the depth is not uniform over large areas, and it would be difficult even to estimate it correctly. In such measurements great accuracy is needed, as a difference of $\frac{1}{100}$ ft. in depth would make a difference per acre of 16 cu. yd. in bulk. Another method, more commonly used, is to count the cart loads removed. Here, too, are difficulties, even when assuming the count to be correct. It is hardly practicable to measure the quantity of snow piled in a wagon within 5%, and this figure may be materially greater. For a depth of 3 in. of snow removed, this would represent an error of more than 20 cu. yd. per acre. Occasionally, it might be practicable to weigh the loaded carts, which would be the best method.

The snow when it has fallen is light, and begins to shrink. It packs closely when wet. In New York City it was estimated in 1907 that the shrinkage, from the time when the snow fell to the time when it was compacted in the carts, was about 70%, indicating that when shoveled into piles and subsequently into carts its volume is only 30% of that which fell originally.

B. COLLECTION

We have assumed that the sweepings, dust, rubbish, or snow have been gathered at suitable points from which they can be collected. The collection should be done with as little offense as possible along the routes followed by the wagons.

1. Piles and Receptacles.—Collection begins at the piles or receptacles in which the material to be removed has been gathered. In New York City the actual distances between piles or receptacles on

the streets are about 260 ft. on the main avenues (or at the street corners) and about 700 ft. on the side streets. The piles should be placed near the gutters, where they can be readily shoveled into the carts with shovels of suitable size and shape, so that the material may be taken up easily in large quantities, and the surface of the pavement left clean. The piles should be at such distances apart as may be found most practicable, depending on the quantity of material to be piled.

In down-town Chicago, curb boxes for street sweepings are placed at each sidewalk intersection and at intermediate points, the distance between boxes being about 200 ft.

The piles should not be too large, requiring the refuse to be swept too far, and they should not be too much exposed to disturbance by wagon wheels or wind.

In some cities, where the street travel is dense, instead of having exposed piles, the men have cans, or small trucks on wheels, into which they put all street sweepings and rubbish, and leave them at the sidewalks to await collection.

As much of the street rubbish originates on the sidewalks, and from there finds its way into the roadway, it is a growing practice to place receptacles at fixed points on the sidewalks, especially for the use of pedestrians and house occupants, and in which all litter or trash can be deposited to await the call of the collection wagon. Such cans should be placed at the curb or at the house lines as frequently as the local necessity demands. The more frequent use of cans would greatly improve the appearance of our streets, particularly in large cities. The better appearance of the streets in many European cities is largely due to this single expedient.

The receptacles or cans should be of metal, and vary in size according to needs. They should be marked plainly so that their purpose is evident, and have painted on them the name of the department conducting the service. Fig. 127 shows rubbish cans used in New York City.

Many cities in Europe have pits on the sidewalk, covered with a lid, in which the cans are placed and filled. The cans are lifted out when the collection wagon passes, and either dumped into it, or placed on it in exchange for an empty can which is set into the pit.

The collection of leaves, due to their lightness, should be confined to calm days, and then be taken with the other sweepings from the same piles or cans, and removed with them. In some cities, having many shade trees, the leaf problem is a large one. Rochester has made some studies of this problem,* and it is suggested that private

* Report on the Problem of Street Cleaning in the City of Rochester, N. Y., by the Bureau of Municipal Research. October, 1918.

parties gather up their leaves for collection and place them in burlap bags, or in barrels other than those for the house rubbish, if a separate disposal is required. The street sweepers may also be supplied with bags, so that leaves can be packed into them from the piles. It is also suggested that private persons either do their own carting or obtain a permit to burn the leaves in wire barrels on their own grounds.

Fig. 127.—Street Rubbish Cans.

When gathering litter from the pavements, the collector usually carries with him a stick having a steel point at the end, with which to pick up and throw the pieces of rubbish into a burlap or canvas bag held in his other hand or attached to a frame on wheels, which is subsequently emptied into a can or wagon. The bag generally has a spreader to keep the top open.

Fig. 128 shows a street refuse receptacle used in Dallas, Tex. It is a galvanized-iron stand, with hinged cover and closed sides, and is

bolted to clips set in the sidewalk. In this is placed a frame holding a bag for the reception of sweepings.

Fig. 129 is a light, two-wheeled cart, with a small supporting wheel at the back, and is used as a can or bag carrier. It is built entirely of iron and steel, the frame being of steel tubing and the platform of sheet steel. The wheels are 30 in. in diameter and the

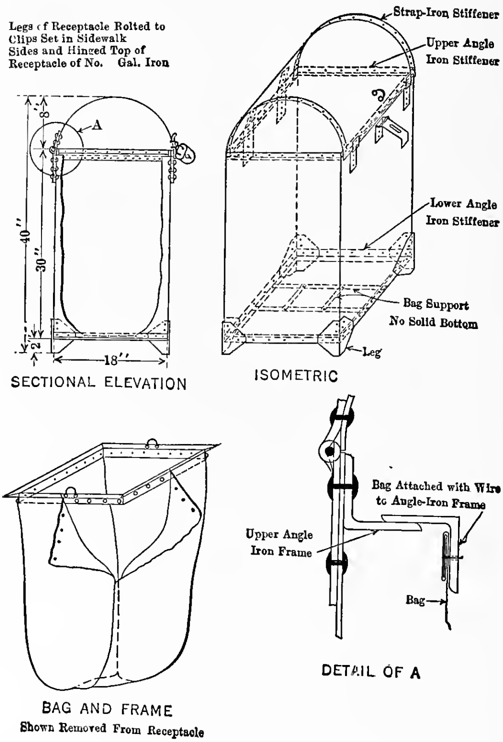


Fig. 128.—Street Refuse Receptacle, Dallas, Tex.

axle is $\frac{7}{8}$-in. solid steel. The can is held in place on the platform by a hook which slides on a supporting bar at the back. The bag holder is a wrought-iron ring having a rod at each side. The bag is folded over the ring and held by two spring clamps. The holder is readily placed in position by inserting the rods into the top openings of the tubular frame of the carrier. This vehicle is made by the Tarrant Manufacturing Company.

2. Wagons.—There are various designs for wagons used for street refuse removal. The design should be such as to make the

loading convenient. Some vehicles have a small light crane attached, to facilitate the loading; others carry an inclined runway with small truck, so that the cans can be rolled up to the wagon; some are arranged to receive full cans and return empty ones; some have a floor only 12 in. above the pavement, to facilitate loading with filled cans.

All wagons should have a cover of canvas or light rigid material, which cover may be left open when receiving the load, and closed when the wagon is full and proceeding to the point of final disposal, thus avoiding danger from having the dust blown about by the wind.

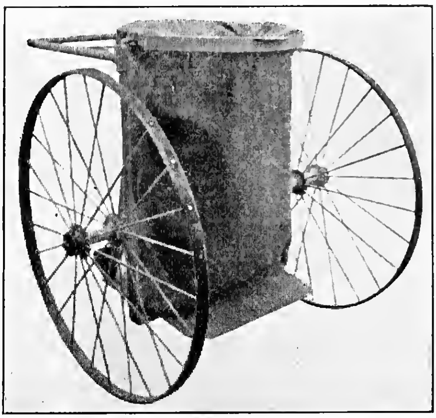


Fig. 129.—Can or Bag Carrier.

The street refuse is dumped into the wagons from the cans, or is shoveled into them by hand from the piles. In the latter case, it is important to have the collecting wagon follow the sweeper as soon as practicable, so that the piled material will not be scattered by wheels passing over them, or by wind and rain.

Mr. Fetherston, in reporting on the street refuse removal of West New Brighton, in 1912, states that the average quantity of street sweepings removed by each unit (cart and driver) per productive working day was 14.1 cu. yd. A test of the collection and removal by a large motor truck proved that there was no economy in the power truck over the horse-drawn vehicle, as the number of stops and the time required to load the truck was not offset by the gain in speed, due to the length of haul to the point of disposal. It is stated, however, that it is probable that a power truck will be found economical in collecting street sweepings which are to be gathered from a large territory, where speed will be a controlling factor.

3. Time.—In the most frequented streets of large cities the trash and horse droppings should be picked up continuously, by a section patrol, and deposited in cans, as is customary, especially in Europe. A thorough street cleaning on busy streets can be done best at hours of least traffic, namely, at night or during the early morning, and when machines can be expeditiously used for sweeping. This has the great advantage of obtaining a much higher degree of cleanliness and a more economical collection. It has the disadvantage that night work is more expensive and often not as thorough. The best compromise seems to be the early morning, which is the customary time in many cities.

4. Organization.—Whether fine and coarse rubbish and snow should be removed by contract or by city force depends on local conditions. Unquestionably, it would be best and cheapest to remove all refuse by a trained city force of men, as mostly done in European cities; but, in American cities, we often get better results, both in efficiency and cost, if some of the materials, particularly the larger quantities of snow, are removed, under rigid specifications, by contract, and under a sufficient number of competent and faithful inspectors.

For the ordinary and steady work of street refuse collection, it has been found much more satisfactory, as well as less expensive, to have a permanent, well-trained corps of men and officers, under an efficient organization, rewarded for their best work, and pensioned after long and faithful service. Streets are continually open to inspection, and the citizens are given great satisfaction when seeing good work done.

C. FINAL DISPOSAL.

The final disposal of street refuse depends somewhat on its value; first, as manure, when applied on fields either directly or as a dilutant; secondly, as a filling material on low land; thirdly, as a heat producer when incinerated; and, fourthly, when, as snow, it is dumped at convenient points. In all cases the disposal should give as little offense as possible to sight and smell, both to the public and to private citizens.

1. Fertilizer.—The fertilizing value is greatest when the material is chiefly horse manure, collected from well-paved streets with smooth surfaces, and kept fairly free from mineral and organic matter which is resistant to decomposition. The use of automobiles has lately increased to such an extent that in some cities, as already said, the quantity of good street manure has become very small, and it is likely to decrease still more.

To ascertain the actual value of the street refuse, average samples should be collected and analyzed. To be worth considering at all as manure, the organic matter in the sweepings should be more than 75%. It is then necessary to ascertain the cost of delivery from the collection point to the farms, which cost determines whether this delivery leads to the most economical disposal, or whether other satisfactory methods of disposal would cost less.

It may be found practicable to discharge manure at intermediate points and to convert it into a compost to be sold for fertilizing. Such a process might be advisable at times when manure cannot be placed on the fields, but would require temporary storage. An estimate of cost may furnish the best answer as to whether or not this is economical.

In ascertaining the cost of delivery, it is necessary to find out whether or not transfer stations are required, to receive the collected sweepings for reloading into cars to be taken to more distant places for disposal.

2. Land-fill.—When it is found that the manurial value is too small to merit the cost of its delivery to farms, and that there is an opportunity to dump it on low land near by at much less cost, it is necessary to determine whether such filling would be satisfactory. It might probably be satisfactory when the putrescible organic matter is less than about 5% in warm or 10% in cold climates. Street sweepings richer than this in manure, and when dumped alone, have been productive of bad odors.

In New York City the sweepings are collected together with ashes, but are only about one-fifth as great in quantity as the ashes. This mixture prevents putrescence, and land properly filled with such a mixture will not be unsanitary after a few years. It is always well to cover such fillings with a layer of about 6 in. of earth. In estimating comparative costs, it is necessary to start at the point of collection.

3. Incineration.—If an incinerator for other refuse is available, with a short haul, then, to reduce the length of haul, and the cost of collection, it is practicable, if the organic matter in the street refuse is greater than 50%, to burn the sweepings either alone, or with rubbish, or with garbage and rubbish.

Whether or not this is preferable to the other methods mentioned can be decided only after both analyses and estimates of cost have been made, including the cost of collection. It is possible that, for the central portions of the largest cities, this method of disposing of street refuse in the future may become the cheapest one, because the expense of transportation to a great distance becomes high.

If collected after rainy weather, and if the final disposition is

incineration, it may be necessary, and may even be economical, to provide for some means of draining and even drying the refuse before discharging it into the furnace. This may be done by temporary short storage under cover, and perhaps also by a short-time heating with waste heat at the works.

In Frankfort a/M. street sweepings are mixed with the precipitated sewage sludge after being centrifuged, and, with other refuse, are then burned.

4. Dumping Snow.—After the snow has been shoveled into carts, it is taken to points of disposal at the nearest places where it can be dumped. They are as follows:

(*a*) Sewers of the combined system which are sufficiently large to receive a certain quantity of snow and to float it to the outfall.

The snow is dumped into the sewer manholes, care being taken to arrange the dumping so that no clogging occurs in the sewers. This is the least expensive disposal, and may be used in many cities, under proper restriction, and particularly when the sewers discharge directly into watercourses. It is not practicable to use the rain-water drains of a separate system for this purpose, as there is no continuous flow of water in them. In exceptional cases, however, they can be used when there is a heavy thaw, but then only under careful examination of the water temperature of the slush forming in the drain, etc.

(*b*) Watercourses that are large enough to float away the snow dumped into them at the banks.

(*c*) Open lots and any near-by territory where the snow can be dumped without harmful results, and where it can await a gradual melting away.

There will rarely be any expense attached to the disposal of snow other than that of collection.

D. SUMMARY AND CONCLUSIONS

All street refuse should be deposited for collection in piles, bags, closed cans, or covered masonry pits, so that no dust will arise, and the dirt after collection will not again be scattered. The wagons should be loaded so that only a minimum of dust arises. This can be done by using proper shovels and by dumping the receptacles carefully. The wagons should have tight or canvas covers which can be opened and closed easily. In some cities closed filled cans are placed on the wagon and empty ones left in their places. The filled cans should be light enough to be lifted by two men or by a small crane attached to the wagon, or pushed up an inclined runway.

As street refuse should be removed as often as required to secure the desired cleanliness, crowded streets in large cities should be cleaned daily. The best time for collection is when the streets are least used, namely, in the latter part of the night, and early in the morning when machine cleaning also becomes practicable.

Ordinances to prevent the littering of streets should be enacted and enforced.

It has been found best, both in America and Europe, for a city to have its own organization for cleaning, although there may be proper exceptions to this rule, such as the collection and removal of snow when it falls in large quantities and must be removed quickly. In this case, and in our country, contract work has generally, as yet, been found better and cheaper.

The best final disposal of street refuse depends on its composition and the distance of haul necessary for its disposal. The best disposal of street sweepings, if economical and if they contain sufficient manure, is for fertilizing purposes. The other methods are: Dumping, if not objectionable, and incineration if combustible. In dumping sweepings which contain more than 5% of manure, it is well to cover them with ashes or soil to prevent fly breeding.

Snow, up to a quantity when clogging would begin, can be dumped into the manholes of large sewers having a good flow. Otherwise, dumping into watercourses and on open lots is the usual practice.

A careful investigation of all the conditions, together with estimates of cost, beginning at the point of collection, should decide the preference.

CHAPTER XVI

NIGHT-SOIL AND DEAD ANIMALS

A. NIGHT-SOIL

Night-soil is the name given to excreta when separately collected and when it does not form a part of house sewage. It originates chiefly in cesspools at buildings in those parts of the outlying districts of cities into which sewers have not yet been extended. There are large numbers of cesspools in many American cities. In Danville, Ill., for instance, in 1916, they were used in 2500 out of 7000 houses.

Solid fæcal matter consists mostly of animal nitrogenous matter, partly digested, and vegetable non-nitrogenous residues of the food. Most nitrogenous matter is easily liquefied, and most vegetable matter is slow in dissolving. Both are first attacked by aerobic bacteria and later by anaerobic bacteria, which slowly putrefy the mass and deposit black sludge.

Night-soil is similar to sewage sludge, but rather more liquid, and, as already mentioned in Chapter II, is pumped or dipped from the cesspools into water-tight wagons, or collected from earth closets.

It is very seldom that the actual quantity of night-soil is recorded. The quantity collected in Winnipeg in the years 1914 to 1918, inclusive, is shown in Table 180. In each locality it depends on the number, size, and tightness of the cesspools, the frequency of emptying, and the extent of the sewer system. The house treatment of night-soil and dead animals has been discussed in Chapter II.

1. Collection.—Night-soil is generally collected by private concerns, licensed by the city, which has regulations controlling their work. The collection is usually made separately, the night-soil not being mixed with any other refuse. The wagons used for this purpose are of various kinds, and some of them are of satisfactory design.

In Atlanta, the night-soil is collected by the City. A special tank wagon, designed by Mr. John Jentzen, Chief of the Sanitary Department, is shown in Fig. 130. The container is a large tank similar to that carried by a sprinkling wagon. The night-soil is pumped to the tank through a manhole on top. When the wagon is to be emp-

tied, the manhole covers are bolted in place and a 4-in. outlet in the bottom is connected to the sewer. Water under pressure is then allowed to enter the upper inlet, and this flushes the night-soil into the sewer and leaves the tank clean.

TABLE 180.—NIGHT-SOIL COLLECTED IN WINNIPEG, MAN., IN THE YEARS 1914 TO 1918, INCLUSIVE

Year	1914	1915	1916	1917	1918
Population from which collections were made:	203,255	201,981	200,090	182,848	183,595
	Weight, in pounds	Weight, in pounds	Weight, in pounds	Weight, in pounds	Weight,, in pounds
January......	201,000	290,000	136,668	145,200	208,000
February.....	207,155	260,600	162,700	133,000	184,000
March.......	200,145	308,276	178,200	216,000	199,500
April.........	481,750	329,375	168,000	192,000	208,000
May.........	598,875	247,304	156,000	182,000	79,000
June.........	503,795	168,700	171,600	187,200	180,000
July.........	937,515	170,000	162,500	208,000	192,000
August.......	665,175	162,700	171,600	197,600	183,300
September....	670,540	162,700	170,000	187,200	192,000
October......	561,475	162,700	165,000	208,000	196,800
November....	332,590	169,208	156,000	197,600	200,000
December....	279,375	169,208	155,000	200,000	184,000
Totals.....	5,639,390	2,600,771	1,953,268	2,253,800	2,206,600

In cleaning cesspools, bricks and other débris are sometimes removed with the night-soil. Care must be taken not to allow such débris to clog the outlet. A basket screen hung in the manhole has been used to prevent this occurrence.

Such " odorless excavators " are used in many cities. In Kansas City the cost of cleaning cesspools and delivering the night-soil at the Missouri River, in 1914, was $8 for a load consisting of from 35 to 40 cu. ft.; and one cesspool generally holds from two to three loads.

Night-soil can be disinfected, and fly breeding prevented, by a cresol solution, dilute caustic, gas-house waste, kerosene oil, or by sawdust.

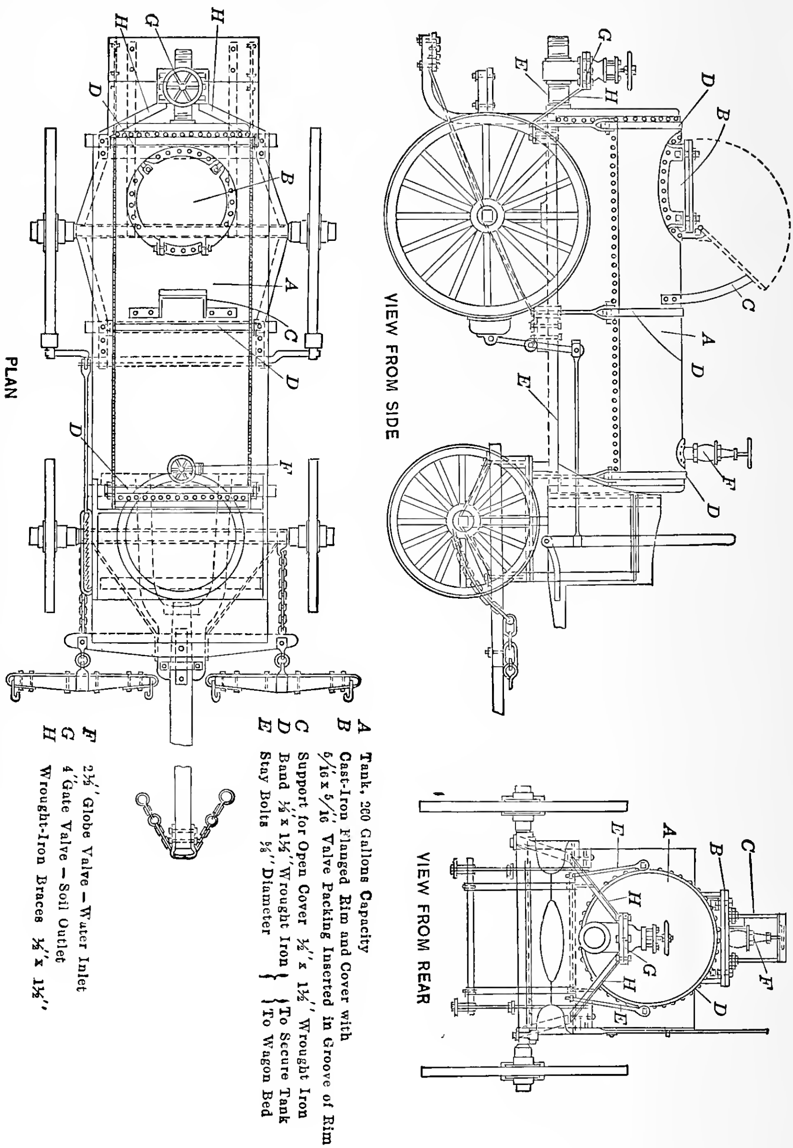


FIG. 130.—Night-soil Wagon, Atlanta, Ga.
(Designed by John Jentzen, Chief, Sanitary Dept.)

In England, formerly, the pail or tub system was commonly used for collecting excrementitious matter. A pail was placed under the privy seat, and, when full, was replaced by an empty one. In 1884 there were about 40,000 pails in Birmingham for a population of 250,000. At best, it was an offensive method, and is now rarely used.

A better system, still used in many places, is the earth closet, where finely sifted earth or clay, ashes, or charcoal were stored above the closet, a certain quantity being caused to spread over a dejection by using a pull. From $2\frac{1}{2}$ to 3 lb. of dry earth, less ashes, or still less charcoal (about one-quarter of the above quantity) are sufficient to remove permanently all odors from an average dejection of fæces and urine. The resulting material is a good fertilizer. Ashes are not as valuable, in this respect, as either clay or charcoal.

In Paris and in other large continental European cities, night-soil, when collected in the absence of sewers, is temporarily stored in cesspools or in strong wooden casks (*fosses mobiles*) containing from 4 to 5 cu. ft. The contents of cesspools are pumped into cylindrical iron carts, containing from 70 to 140 cu. ft., which are tightly covered. They, and also the wooden casks, are taken to places outside the city where the contents are spread on land as a fertilizer, or are taken to depots where they are converted into poudrette. The collections are made at brief intervals—several times a month—and are generally very regular; the containers are well cleansed before they are used again.

2. Disposal.—Night-soil is disposed of in several ways. In Kansas City it is dumped directly into the Missouri River. It should not be dumped at the shore, but into the current. In Atlanta, Columbus, Pittsburgh, and many other cities it is conducted through a large hose directly into large sewers through street manholes. This is the proper place for night-soil, if not used as a fertilizer, because the sewers, in the future, will receive the sewage from the same houses from which at present night-soil is removed separately.

In some cities a special building is provided where the wagons enter and dump into a branch sewer leading to the street main sewer, to be followed by a good flush of water to cleanse the branch. With proper equipment and good service, this method of disposal is unobjectionable.

In Winnipeg, the night-soil is discharged into the sewers during the summer, but during the winter it is spread on agricultural lands outside of the city.

In a few places it is burnt in furnaces with the garbage; in a few others it is plowed into the earth on fields.

At Montgomery, Ala., there is a station,* for disposing of can-

* Described and illustrated in *The Municipal Journal and Public Works*, Aug. 9, 1919.

collected excrement or night-soil, designed by E. B. Johnson, Chief Sanitary Inspector of the U. S. Public Health Service.

In establishing such a station, its location was of first importance, as objectionable odors would become a source of complaint by near-by residents. The proper equipment and management are of equal importance, as the building and the persons of the attendants must be kept clean.

A plot of ground, 150 by 100 ft., on a bluff overlooking the Alabama River, was selected. The nearest dwellings are about 300 ft. distant, and not more than twenty are within 700 ft. Within a radius of $1\frac{1}{2}$ miles there are 3300 privies in which 3900 cans are used. The station was built in the center of the plot, thus securing free ventilation and a reasonably clear zone between it and adjoining property.

The platform space was designed to accommodate 700 cans a day, not more than 200 to arrive at one time. An allowance for extension was based on the possibility of 480 arriving at the same time, so that the capacity would be more than 10,000 cans a week. As the cans are changed once a week, the station could dispose of the excreta of two and one-half times as many houses as are in the present territory.

To provide for 480 cans at one time, a 30 by 7-ft. unloading platform was built, and a loading platform of the same size on the opposite side for empty cans. A width of 6 ft., between the platforms, was allowed as a working space. Fig. 131 is a plan and section of the station. Brick piers, 5 ft. apart and of sufficient height to bring the floor from $2\frac{1}{2}$ to 3 ft. above the driveway, support the structure. The stringers are 4 by 6-in. timbers and the flooring is of 2-in boards. The sides and roof are covered with corrugated galvanized iron.

As originally designed, only the central part, 6 ft. wide, was roofed. Experience has shown that it would have been better to extend the roof over the entire platform and enclose the sides with rolling or sliding doors, in order to shelter the attendants and protect the equipment against theft and depredation. It is also proposed to provide future stations with a concrete floor and a central drain. There is a cinder roadbed from the street to the station and around it.

Three concrete hoppers receive the contents of the cans. Each is shaped like an inverted frustum of a cone, and has a lip extending 12 in. toward the unloading platform. The lip is U-shaped, and the lowest part, inside, is about 7 in. below the top. On the inner wall of the hopper, and level with the inside bottom of the lip, four pieces of angle-iron are placed at equidistant points. These are bolted to the hopper so that their edges project into it and form a support for the can. The diameter of the hopper at this level is 17 in. and that of

the cans is 15 in. The hopper is connected with an 8-in. sewer which discharges into the current of the Alabama River.

The cans are washed by a ½-in. pipe which projects into the hopper and rises 2 in. above the angle-iron supports. The flow from this pipe is controlled by a Titan valve just outside the hopper. This valve is

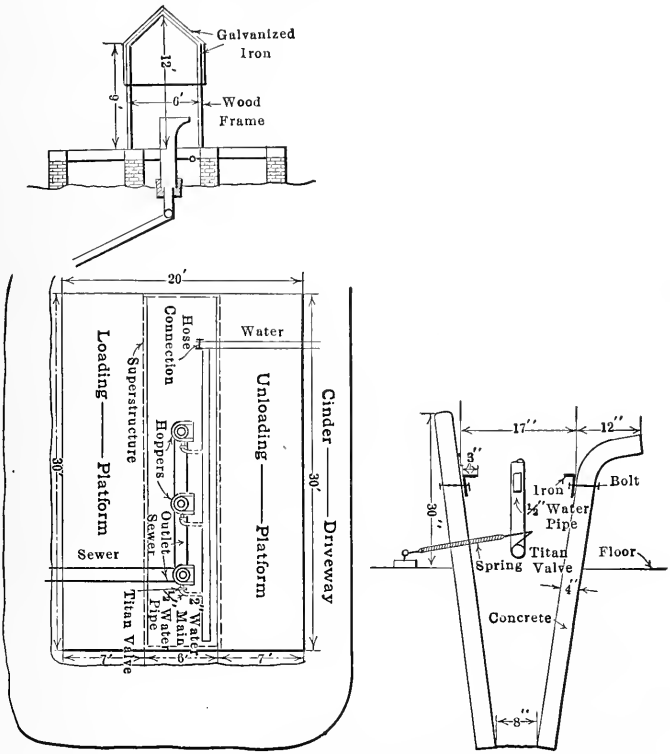


FIG. 131.—Plan and Section of Station for Disposal of Night-soil, and Section of Hopper, Montgomery, Ala.
(From *Municipal Journal and Public Works*, Aug. 9, 1919.)

kept closed by a spring, and is opened by a lever and kept open during washing by foot pressure of the operator or by a weight placed on the lever. The washing pipe is connected to a 2-in. pipe fed by the city mains.

The full cans are unloaded from the wagon by the driver and two helpers. The wagon is then driven to the loading platform and receives a load of empty cans. The handling and cleaning of the cans is done by two men under the direction of a foreman. One man

operates on the " soiled can " side, placing the cans in the hoppers, and the other man, working on the opposite side, removes and places them on the " clean can " platform. The full can is inverted over the hopper, thus discharging the greater part of the contents. Then the water is turned on and allowed to flow for from 40 to 60 sec. This is nearly always sufficient to clean the can, as only in about one case in a hundred do fæces adhere to the inner surface after washing. In such cases this material is loosened by applying a solution of lye with a mop. The lye is reported to have had no bad effect on the galvanized iron.

In other stations, the cans, after mechanical cleaning, are immersed in a disinfecting solution (such as 1–50 compound cresol), leaving about a pint of the solution in the can.

The covers of the cans are washed on the platform with a hose.

There is only a slight odor at the station, as the cans are kept tightly covered until they are placed in the washing hoppers.

The station was built during the war, when the cost of labor and materials was high. The items of expense connected with its erection and operation were as follows

Cost of construction:	
Ground	$1500.00
Station and hoppers	768.40
Sewer, water pipes, and fixtures	931.60
Total	$3200.00
Cost of operation per day:	
Foreman	$4.50
Two laborers, at $2.50	5.00
Total	$9.50

This force handles 700 cans daily, and, if necessary, it could care for 1200 cans in the same time.

B. DEAD ANIMALS

The house treatment of dead animals has been discussed in Chapter II. In large cities the collection and disposal of dead animals is a proper function of the municipality. Many small dead animals are thrown into the street for the city scavenger to pick up. This should not be done, except with the permission of the police, and on immediate notification of the proper department. The work of collection is done generally by city teams, though sometimes by licensed scavengers or by a general contractor. Dead animals larger than cats and small dogs should always be collected separately, and not mixed with refuse.

Trucks for the removal of dead horses should be hung low, to avoid an excessive lift.

In Chicago, a private company, operating under a five-year contract, collects and disposes of dead animals. The City is paid a nominal sum per year for the privilege. The contractor agrees to remove within twelve hours all dead animals from all streets, alleys, and the river, except in the stock yards district, and to dispose of them at least 3 miles outside of the city limits. A summary of the work done during the 12 months ending, August 1, 1913, is as follows:

Item	Average weight per animal	Total weight
Horses	1300 lb.	9,253 lb.
Dogs	25 lb.	20,782 lb.
Cats	5 lb.	3,603 lb.
Miscellaneous	100 lb.	448 lb.

Table 181 shows the number and kind of dead animals collected in Washington, D. C., from 1906 to 1908 and 1915 to 1918. The collection and disposal is by contract. It has been recommended that in the future all dead animals be collected in closed vehicles so that they may be entirely out of sight while passing through the streets.

TABLE 181.—DEAD ANIMALS COLLECTED AND REMOVED IN WASHINGTON, D. C., IN 1906, 1907, 1908, AND 1915, 1916, 1917, AND 1918

Year	Horses	Mules	Cows	Goats	Dogs	Cats	Chickens	Rats	Miscellaneous
1906	417	....	42	....	4471	5,783	367	775	120
1907	649	....	54	....	4899	7,574	488	1065	163
1908	614	....	67	....	7666	9,058	380	1209	187
1915	565	23	17	23	4953	14,362	195	311	113
1916	578	14	15	22	5368	16,093	151	333	150
1917	576	27	12	4	5724	17,469	184	424	142
1918	616	29	15	6	7271	14,401	255	172	126

The weight of dead dogs collected in Winnipeg, from 1911 to 1914, as shown by the annual reports of the Department of Public Health, was as follows:

1911	18,840 lb.
1912	27,080 lb.
1913	40,950 lb.
1914	36,150 lb.

The number of dead animals reported as collected in Milwaukee and Columbus for 1913 to 1916 was as follows:

	Milwaukee	Columbus
1913	....	287
1914	5133	183
1915	4914	233
1916	4769	157

Table 182 shows the number of small dead animals collected and disposed of in Milwaukee in 1919, and the cost thereof.

TABLE 182.—COLLECTION OF SMALL DEAD ANIMALS IN MILWAUKEE, IN 1919

Month	Small animals	Cost of collection
January........	224	$130.00
February.......	218	120.00
March.........	248	137.50
April..........	294	130.00
May...........	294	135.00
June...........	406	195.00
July...........	398	265.00
August.........	392	260.00
September......	320	260.00
October........	283	135.00
November......	243	125.00
December......	216	135.00
Totals.....	3536	$2027.50

Average cost of collecting each animal, $0.57.

Dead animals are almost always disposed of at private rendering plants, even in the smaller cities. The hides are removed from the larger animals, and the carcasses are treated to secure the grease and tankage. In Milwaukee, and generally in other places where there are incinerators, the smaller dead animals are burned with the mixed refuse. In 1918 the average cost of collecting small dead animals in Milwaukee was $0.47 each.

The collection and disposal of dead animals requires considerable attention, in order to avoid nuisance and danger to health.

In Europe, and particularly on the continent, the collection and disposal of dead animals has received much attention, both by gov-

ernments and individuals, and in the interests of sanitation, agriculture, and commercial products. The following gives a description of a method of collection.

Suitable vehicles, formerly horse-drawn, now motor trucks, collect even partly decomposed bodies satisfactorily, and on poor roads. The wagon bodies are tightly closed, so that neither air nor liquids can escape. Zinc linings were tried, but the jarring frequently caused cracks and rupture. Sheet-iron, welded at the joints, resting on a wooden floor and supported by a wooden frame, proved to be better. Still better was a design, by Kunz, completely of sheet-iron, the lower third of which was a tray having a round bottom which could be drawn out at the rear, the upper two-thirds being firmly attached to the chassis. Dead animals could be readily put into the tray, lifted by a winch, and pulled into the wagon. The capacity of the wagons is from two to three tons. To reduce jarring, wheels of large diameter were placed under the center of the body and smaller wheels in front.

The oldest method of disposal—still much used—is burial, but, for large animals, there must be a deep, and not a shallow, burial, in order to destroy all pathogenic bacteria effectively. Another common method was a treatment with strong mineral acids, such as concentrated sulphuric acid. This was applied for twenty-four hours and the resulting mass was then mixed with bone meal. When dry it is a good fertilizer, and contains as much as 4% of nitrogen and 16% of phosphoric acid. This process, developed by Girard, has been used in France.

The most sanitary disposal, and a necessary one in the case of diseased animals, is by incineration. On account of the odors arising, the primitive burning in the open field has been supplanted by portable crematories or fixed incinerators. This method does not utilize the material, as the ashes have no high manurial value. The portable crematory consists of a horizontal wrought-iron cylinder lined with fire-brick and mounted on four wheels. Between the rear wheels there is a fire-box, separated from the cylinder by a grate. The dead animal is lifted in at the front end, under the stack, and the cylinder is then tightly closed. A horse is cremated in six hours with 500 lb. of pine wood, and without odor. An advantage of this apparatus is that it can be taken to the dead body, and avoids taking the latter, when exposed, through the streets, which is inadvisable if death was caused by an infectious disease.

Fixed incinerators, designed especially for burning dead animals, are not usually built in American cities, but incinerators for general refuse are usually arranged to burn also large animals. Care must be

taken in this case to place the body in the combustion chamber, where the heat is highest and all organic gases can be destroyed.

The common method for disposing of dead animals in European cities is to reduce them to grease and tankage, which are both salable. On the continent, Podewils has devised the best apparatus; the Grove system was less satisfactory. Cooking with steam under pressure is used to separate the grease from the water and other matters. The grease is drawn off, the water is evaporated, and the remaining gelatinous material, or glue, is sold, or is mixed either with the tankage or with the bone meal and sold as fertilizer.

The waste water, however, has generally been turned into the sewer, as evaporation is expensive. It is sometimes advisable to have prior sedimentation. Where there were no sewers, a purification by intermittent land filtration has solved the problem.

The tankage is sometimes ground to a meal and, due to its contents, has served successfully as a food for hogs. Its value for this purpose has been estimated in Europe at $2 per 100 lb., whereas it has brought less than half of this price as a fertilizer. The grease has been sold at $5 per 100 lb., and is used as a lubricant, or in soap making. The glue is not salable as such, because it has been subjected to a high degree of heat. It has been sold, however, at $1 per 100 lb.

The largest recent municipal establishment for disposing of dead animals is in Ruednitz, near Berlin. It is said to be the largest and best arranged on the continent. The works are very carefully designed to prevent odors and avoid all possible contact between the dead raw material and the products. The former are delivered at one side of the building and the products are removed from the other, the two parts of the building being separated by a wall having a few tightly closed doors, and the workmen are not allowed to pass from one part to the other. All vehicles are thoroughly disinfected before they leave the premises.

The ordinary dead bodies are skinned and then cut into pieces. Skins, horns, and hoofs are passed into the other part of the building, there to be treated and made ready for sale. The other material is treated by boiling, which separates the mass into grease, bones, liquids, and tankage, as in garbage reduction works. The grease is drawn off into barrels and sold. The tankage is ground fine and sold as a fertilizer, and sometimes for feeding.

Adjoining the building are the dwellings of the workmen, with hot and cold water bathing facilities, dining rooms, etc., and with good ventilation and electric lights.

Diseased bodies and those partly decomposed are treated differently in a separate part of the building. The workmen change their clothes

before leaving the works. Dissecting rooms are provided, and a special disposal of the different parts is ordered, according to the results of examination.

The ordinance permitting the erection of the Ruednitz establishment states that it must be under the direction of a veterinary surgeon. It must never be leased, but be under the immediate supervision of an experienced city officer. A well-trained corps of men is a further condition for the operation of the plant. About thirty men are employed.

C. SUMMARY AND CONCLUSIONS

Night-soil requires special collection and treatment when it does not form a part of house sewage going into sewers. It is collected, in the outlying districts having no sewers, either from cesspools or special receptacles, and generally by private, but licensed, concerns. Municipal regulations, carefully drawn up, should control the house treatment, collection, and disposal.

The collections are made at stated intervals, in wagons specially designed for the purpose, and usually called " odorless excavators." The material is generally pumped into them, and is not exposed so that it emits any odor. Cleanliness in all parts is essential, both in the house treatment and the collection.

The final disposal varies in different cities and countries. In some American cities it is dumped into large rivers, because this is most economical. In others it is dumped at night into large sewers through their manholes as a thick liquid. Some cities have it spread over agricultural lands, particularly in the winter, or plowed in, or burnt with the garbage. In Europe night-soil is generally converted into poudrette to be used as manure.

Dead animals require disinfection, when at the houses, and an early removal under the supervision of the municipality, which must be immediately notified. They are collected by the city or its licensed scavengers. Small animals, as rats and mice, generally go into the garbage. Large animals are collected separately, for which special vehicles are sometimes provided. These are generally closed so that the bodies are out of sight.

The disposal is generally in private rendering establishments, the hides being sold and the carcasses reduced to secure grease and tankage. Where no such establishments exist, the dead bodies are buried.

CHAPTER XVII

PROCEDURE IN SMALL TOWNS AND VILLAGES

In very small communities, with populations ranging from a few hundred persons to 15,000 or 25,000, the refuse disposal problem generally requires a different solution than in large cities. This is apparent from a brief consideration of the different conditions. First, there are different types of small communities. There is the residential town contiguous to a large city, forming part of a large metropolitan district. Such a town may be used, almost wholly, for residential purposes, and, therefore, it may be difficult to find a suitable location for a refuse disposal plant. Another type is the small county seat in the midst of a farming district, possessing one or more small industrial plants and surrounded with large open spaces and many farms. A third type is the small industrial town, through which run two or more railroad lines. A fourth type is a town with a low valuation of its property and a consequent shortage of public funds. Some of these characteristics vary also with the climate, topography, soil, and other conditions.

A small community has generally less trouble with the disposal of its solid refuse than a large one, because the quantities to be dealt with are small; the distances to which they can be delivered and satisfy all requirements are short; the necessity for a general system of collection and disposal is less serious; and it is practicable in many instances to allow some liberty to each citizen to select a disposal of his refuse most satisfactory to himself.

A. TYPICAL CONDITIONS

Prior to the establishment of any general collection service, it is often found that garbage is collected by one or more private scavengers, who make arrangements with each household and dispose of the garbage by dumping it on waste land without proper public regulation, or by feeding it to hogs. Nuisances often result in both cases. Generally, the cost of this service is paid by each customer, the

monthly charge in some towns in Illinois and New England ranging from $1 to $4, or 10 cents per can. In Decatur (population, 40,000), the charge is 40 cents per month per family. (1915.)

It has been found that in some communities the collection is from not more than one-fourth of the population. The cost per family is therefore sometimes high, and covers only a restricted service. In one Illinois city of 3500 population, where garbage collection is thus provided for about 25% of the people, the annual sum paid to the scavengers in 1916 was about $8000, a sum nearly sufficient to pay for a service covering the whole town under one management.

Too often there is no regular removal of rubbish, or even of tin cans. Individuals accumulate their rubbish in the yards. From time to time it is hauled to vacant lots, where the papers blow about and the tin cans form breeding places for mosquitoes. Both papers and tins are unsightly, and disfigure the neighborhood. When rubbish accumulates in large volume, particularly the comparatively incombustible portions, such as glass, crockery, old shoes, etc., its disposal becomes a burden to householders. To relieve this condition, spring clean-up campaigns have been organized; but, in the absence of some proper system of disposal, the nuisance is often only transferred from one place to another.

Ashes, perhaps, give the least trouble in a small town, because they make a good fill and can be used for extending roadways into undeveloped districts. Promiscuous dumping into ravines or woods has sometimes marred some of the natural beauties of the town.

The disposal of manure and night-soil are allied problems, and in small towns may not be as difficult of solution as the disposal of garbage and rubbish; but any method which reduces the number of flies and thereby the fly-borne diseases (Chapter XIV), is as important as in large cities.

B. STATE LAWS

A number of the officials of State Boards of Health have come to realize the need of better refuse disposal in small towns, and in some States laws have been enacted to enable towns to levy a special tax for this purpose, thus providing the necessary funds. The recent Illinois law for this purpose is as follows:

"A Bill

"For an act to authorize cities and villages having a population of less than 100,000 to levy a tax for the purpose of collecting and disposing of garbage.

"Section 1.—Be it enacted by the People of the State of Illinois repre-

sented in the General Assembly: That the city council of each incorporated city in this State, whether organized under the general law or special charter, having a population of less than 100,000, and the president and board of trustees of each village in the State of Illinois having a population of less than 100,000, shall have the power to establish and maintain garbage systems or plants for the collection and disposal of garbage in such city or village, and may levy a tax not to exceed two mills on the dollar on all taxable property in the city or village, according to the valuation of the same as made for the purpose of State and county taxation by the last assessment, in said city or village for such purposes. Said annual garbage tax shall be in addition to the amount authorized to be levied for general purposes as provided by Section 1 of Article 8 of 'An Act for the Incorporation of Cities and Villages' approved April 10, 1872, and all amendments thereto."

In a typical Illinois city of 15,000 people, the tax levy has produced about $8000 per year. (1915.)

C. COLLECTION AND DISPOSAL

To improve objectionable conditions in small communities requires sufficient funds, an organization, and places for proper disposal. Proper organizations and funds are often lacking, as well as a plan for progressive development with full utilization of the existing natural advantages. In reference to this, it is important to note that sometimes, in very small towns, sanitary activity is not far developed. There may be no full-time health officer; and food, milk, and water inspection may be neglected. There may be a need for water filtration or sewage disposal, or even the construction of sewers; and the merits and costs of these more important improvements should be considered in advance of refuse disposal. Yet the latter should always be kept in mind, and a proper balance of the funds of the community should be preserved and expended for the solution of the refuse problem when it may become desirable.

As soon as this problem demands serious consideration, competent parties should begin to investigate the three general features: house treatment, collection, and final disposal. For the consideration of details, reference should be made to the respective subjects elaborated in the previous chapters.

It is pertinent here, first, to mention particularly those collection and disposal procedures which are adapted especially for small towns. The requirements for house treatment will be referred to later.

Of first importance is a general comprehensive collection of garbage at regular intervals, about twice a week, but in summer daily if practicable, particularly in the warmer climates. Covered wagons of good design and proper size should be provided, washed daily, painted

frequently, and kept in good repair. A capacity of from 27 to 54 cu. ft. is generally suitable, although special conditions may require larger wagons. It would be of advantage to have the collectors uniformed, either in duck or khaki.

The collection of garbage should be done preferably by the town, and paid for out of the general fund, or by a special tax, and the service should include practically every house. If the collection is left to individual agreement, on monthly payments, generally too few are ready to pay for such a service. In some towns the work is let to a contractor on the basis of a monthly payment for collecting from the whole town. With a conscientious contractor, and sufficient inspection on the part of town officials, this arrangement has proved satisfactory. Generally speaking, however, collection by contract is only advisable when there is no official available to take charge of a management by force account. If the work is done municipally, it should be directed by a competent superintendent (town manager, or superintendent of streets, or commissioner of public works). The horses may be owned and stabled by the town, or hired by the month. The wagons, however, should preferably be provided and owned by the town. (Chapter III.)

Of next importance is a suitable and economical disposal of the garbage. The methods usually available for small towns are feeding to hogs, shallow burial, or incineration. Each of these methods is in successful use in a number of towns.

If a farm in a suitable locality is available, garbage disposal by feeding to hogs is not only the best but also the least costly method. Garbage produced in small communities can almost always be gotten rid of in this way, and farmers are generally willing to collect and sometimes even to pay for it. (Chapter VIII.)

When there is no public collection, and garbage cannot be disposed of by feeding or burial, there is still a method left to the householder, viz., by burning it in the house. To burn it in the kitchen stove, as often done, is usually offensive. A much better way is to put it into a specially made apparatus, forming a part of the flue above the kitchen range, and allow it to be slowly dried, carbonized, and then charred, when it can be taken out and used as fuel in the range. See page 90.

Shallow burial is not costly where suitable soil can be had. It usually calls for the lowest initial investment, and leaves the soil so that sometimes the property can be resold to advantage for farming. (Chapter VII.)

In small communities a disposal of garbage by incineration meets with several difficulties. It requires a large investment cost, and, unless garbage can be burned together with other refuse, the opera-

tion cost is high. A further difficulty, compared with large cities, arises from the fact that the local refuse varies much more per hour and day. It requires an experienced and able management, which is not always available in a small town or village. Consequently, some existing town furnaces in the United States, often both improperly designed and operated, have frequently been unsatisfactory.

The next desirable step is to consider the collection of rubbish. It can be collected mixed with the garbage if the refuse is to be burned. When rubbish is to be collected separately, special rubbish wagons should be secured. They should call at each house once every ten to fourteen days. During the interval the householders should bundle the rubbish or store it in a barrel. In a small town, with average conditions of haul and distribution, one collector should be able to collect the rubbish from 75 to 150 houses per day, depending on the density of the population.

The disposal of rubbish in small towns should not be by dumping, unless this is unavoidable, because of the unsightliness, the settling of the fill; and also because promiscuous fires may be unwittingly started, thus producing bad odors which may be hard to control. The best way for most small cities to dispose of it is by burning, in a common incinerator, preceded sometimes by sorting. Certain materials, amounting to perhaps as much as one-third of the total weight, can be picked out and sold. The portion which is not marketable should then be burned.

The advisability of sorting the rubbish of a particular town depends partly on the sanitary aspect and partly on the market prices of the recoverable articles. With a favorable market, rubbish sorting can be made to yield a slight margin above the operating and fixed charges. It should be a local question whether this margin is worth the undertaking. Promiscuous scavenging should be prohibited.

To prevent accumulations of tin cans in vacant lots is another desirable object for a small town. The cans are first collected with the garbage or rubbish. If the garbage is buried or incinerated, the smaller tins can be disposed of with it. After burning, they crumble and compress more easily, and can be dumped with the ashes from the incinerator. The large tins, and also the small ones, are occasionally compressed into small bales in a hydraulic press, and may then be dumped, or may be shipped to manufacturers for making sash weights or other ware. Clean tins may be shipped to detinning establishments or may be punched into roofing washers. A bid of $5 per ton for clean tins, f.o.b. cars, was received at Danville, Ill., in July, 1916.

Ashes, if not mixed with other refuse, may be dumped for filling

in any low spots or for road making. To prevent dust from rising at dumps, it is advisable to cover ashes with a few inches of earth.

In small towns the streets are not generally cleaned. Therefore, there are often no sweepings to be removed. However, such removal is closely connected with that of other refuse, and can generally be handled by the same officer. Plans for refuse disposal, however, should be made to include the material from street cleaning. When there are sweepings in small towns, and even when they are collected alone, they may safely be dumped for filling low land.

In planning a refuse disposal system for a small community having limited areas available for dumping, these areas should be reserved for street sweepings and material which can be safely dumped, and not for that which can be better disposed of in other ways. The dumping of ashes is commonly resorted to, if they are not mixed with garbage. In England the ashes are mixed with the garbage and rubbish, and the mixed refuse is burned in an incinerator of the high-temperature type. This disposal is common there because dumping is rarely practicable for lack of available waste land.

Stable manure, probably in all cases, can be disposed of on fields within a reasonable length of haul. Where this, however, is not practicable, it may be disposed of for filling in low land, and covered with about 6 in. of soil. Such ground, made of decomposing material, will shrink and settle as the decomposition proceeds. (Chapter VIII.) If an incinerator is available for burning other refuse, it may be found economical under some conditions to burn also the manure.

Night-soil can be treated like stable manure, but as it is more susceptible to rapid putrefaction, if exposed to moist and warm air, it should be well covered immediately, both when used as manure or compost on fields and for shallow burial. It may sometimes be safely dumped into the currents of large bodies of running water. It is also sometimes burned, but never economically. (Chapter XVI.)

Dead animals, unless they are collected by authorized parties for rendering purposes, are best disposed of by burial at convenient and suitable places. The best material for burial is sandy soil, with a covering of from 1 to 3 ft., with good natural drainage, but with the percolating water not entering a source of water supply within several hundred to upwards of 1000 ft., depending on the porosity of the soil and the grade. Soil saturated with water is objectionable for burial. A loose loamy soil having some porosity is much better than pure clay. Unobjectionable decomposition is then produced by oxidation through bacteria requiring air for their activities. It takes place, therefore, near the surface, instead of at great depth, and in porous rather than in compact soil. (Chapter XVI.)

When a town has grown sufficiently to make combined incineration practicable and economical, a careful study of the facts should be made. If appearing economical, other conditions should also be considered: First, the location must not be objectionable; secondly, in a small community, as the quantity of refuse is mostly insufficient for continual burning, intermittent burning is necessary. Where there is enough material only for operation during daytime, the fires can be banked for the night. It is better, as a general rule, although more costly and requires more skill, to have larger furnaces and to operate them once daily for a few hours, or two or three times a week, letting the fires go out between the runs. The latter practice necessitates starting the fires with selected and easily burning materials, such as paper and wood, which do not create offensive odors. Starting a good hot fire with these materials before any garbage or other odor-producing material is thrown in, will not give objectionable odors to the escaping gases.

In Chapter X the disposal by incineration has been discussed from a general point of view, including the furnaces receiving mixed refuse (high-temperature), and those receiving only garbage and sometimes also rubbish (low-temperature). In small American communities the former, even when properly conducted, have not usually been found economical, and therefore the latter are practically the only ones that have received consideration.

In order to get the best operation, it is of first importance to know the character of the refuse that will be available, and the calorific value of the separate parts, as well as of any mixture that may seem to be obtainable and economical. The result will then indicate whether any fuel, and how much, should be added in a given case to secure satisfactory combustion.

The mixture may sometimes be able to produce steam, for which a higher temperature will be required. On the other hand, steam may not be desired, and a low-temperature furnace may be sufficient. Yet, as a nuisance may sometimes arise if the temperature is less than 1200° Fahr., it is desirable, when operating the furnace, to manage the fires so that the temperature will not fall below that figure. Incineration of refuse in a small town requires a sufficient investment for operating cost to obtain satisfactory results, and if the quantity of refuse is not enough to permit the continuous operation of the furnace, the unit operating cost will be correspondingly high.

Preliminary designs and estimates of cost, both of construction and operation, should be made, even in small towns, in order to determine the best method of disposal.

To recapitulate, we find that small communities generally have

less trouble than large cities in disposing of their solid refuse, partly because some of it can be readily taken care of on the premises. When this is no longer satisfactory, the first community effort should be to collect the garbage, and then to dispose of it in a proper way, either by feeding or burial. Later, it becomes desirable for the community to collect also the rubbish, and to destroy it properly. This is best done by incineration. When ashes are collected by the town, it becomes a question whether a separate dumping or other utilization is most economical and preferable. If the ashes are mixed with garbage and rubbish at the houses, as the town grows larger, a combined incineration may be advisable, perhaps producing steam and clinker, as done extensively in Europe. When some ashes are surreptitiously mixed with the garbage, a low-temperature furnace will not work properly. Tin cans may be compressed into bales, and either dumped or sold as old iron.

Thus a town may adopt a progressive plan as funds permit. Such a plan, as a whole, should, of course, be adjusted to each locality by one who is experienced in refuse disposal work. In some cases it will be feasible and desirable to build an incinerator when the collection service is first started, but it should never be in advance of a good collection system.

D. HOUSE TREATMENT AND ORDINANCES

The house treatment and general ordinances to govern this service should be adjusted to the plan adopted for disposal. Many householders would be willing to wrap the garbage in paper before placing it in the can. This is a good practice, except in the case of hog feeding, and may be considered in determining the general plan.

In most small communities there are no adequate ordinances covering the refuse disposal problem. In some, regulations were adopted from time to time, but resulted either only in a partial solution of the problem, or in conflicting measures. In larger cities the ordinances are prepared by better equipped legal departments, and are usually more comprehensive. An outline for an ordinance for a small town is given below. It is somewhat more complete than is often required, but may readily be adjusted to local conditions.

"AN ORDINANCE defining refuse materials and establishing proper sanitary methods for handling and keeping such materials on any premises whatsoever in the city of * * * * .

"SECTION 1.—*Definitions*: The general term 'refuse' is defined to be the more or less solid waste resulting from the activities of the inhabitants of the city, exclusive of sewage flowing in pipes, sewers, or upon the ground, and

night-soil from privy vaults, dry closets, and other such places. The six materials making up refuse are defined as follows:

(*a*) *Garbage* is the organic waste matter, both animal and vegetable, from houses, kitchens, restaurants, hotels, hospitals, etc. It comprises chiefly waste food.

(*b*) *Ashes* are the residue from fires in houses, schools, churches, stores, hospitals, business establishments, etc. This waste is almost wholly inorganic, and includes at times small quantities of glass, crockery, dirt, sweepings, dust, brick, metal, and other inorganic materials.

(*c*) *Tins* are defined as the empty tin cans in which foods have been preserved, including also discarded tin and metal ware, both large and small, from houses, stores, restaurants, hospitals, business establishments, etc.

(*d*) *Dead animals* are defined as those larger than a cat. Dead animals the size of a cat and smaller, are defined as garbage.

(*e*) *Manure* is defined as the cleanings from stables, including straw, shavings, leaves, animal droppings, etc.

(*f*) *Rubbish* is defined as being all refuse materials not included as garbage, ashes, tins, dead animals, or manure. It consists chiefly of wood, paper, rags, bedding, excelsior, straw, leather, rubber, old furniture, stoneware, glass, boxes, barrels, sweepings from buildings, etc.

" SECTION 2.—*Separation of Refuse Materials:* It shall be the duty of all occupants of buildings to keep these refuse materials separated from each other in proper receptacles provided for the purpose, as hereinafter specified.

" SECTION 3.—*Receptacles:* Proper receptacles shall be furnished, and maintained in good and clean condition by the occupants of all buildings, for the refuse materials defined above. These receptacles shall conform to the following descriptions:

" (*a*) *Garbage* receptacles shall be made substantially of metal, and provided with tight-fitting covers and strong handles. Each can shall have a capacity of not more than 15 gal. Cans shall have a diameter equal to at least three-quarters of their height. If one can is not sufficient to hold the quantity of garbage accumulated between collections, a sufficient number of cans shall be provided.

" (*b*) *Ash* receptacles shall be of metal or wood, strongly built to stand the wear and tear of handling, and shall be fitted with tight-fitting covers and strong handles. Each receptacle shall have a capacity of not more than 40 gal. If one receptacle is not sufficient to hold the quantity of ashes produced between collections, a sufficient number shall be provided.

" (*c*) Receptacles for *Tin Cans* shall be of metal with tight covers and strong handles. Each receptacle shall have a capacity of not more than 30 gal. If one receptacle is not sufficient to hold the tin cans accumulated between collections, a sufficient number shall be provided. Large tin cans shall be stacked compactly near the receptacle for tin cans.

" (*d*) No receptacle need be provided for most of the *Rubbish.* It shall be securely tied up in bundles of convenient size to be easily carried away by one man and deposited in a collection wagon. Other rubbish, such as sweepings, should be put in the ash barrel.

"(e) *Manure:* Every person who maintains a stable in which animals are kept, shall provide a receptacle of wood or concrete for the storage of the manure. These receptacles shall have a capacity of at least 10 cu. ft. for each animal stabled. Each receptacle shall be water-tight and fly-tight, and shall have a heavy, tight-fitting, self-closing cover, which shall be kept closed at all times except when manure is being placed therein or removed therefrom.

"SECTION 4.—*Location of Receptacles:* Receptacles for house refuse shall be kept in an accessible location near the rear door of the house. This location shall be arranged to facilitate the removal of the refuse by the collector. Receptacles for manure shall be placed where they can be reached conveniently by the collector. In all cases the location of the refuse receptacles shall be subject to the approval of the Commissioner of Health. Ash receptacles may be kept in the basement, except on special days provided for their collection.

"SECTION 5.—*House Treatment.*—All receptacles for house refuse shall be kept in a clean and sanitary condition, free from cracks, leaks, loose covers, etc.

"SECTION 6.—*Stable Treatment:* All manure at stables shall be treated between May 15th and October 15th with a chemical or other substance which will act as a satisfactory disinfectant and repellent to flies. Suitable fly traps may also be prescribed by the Commissioner of Health. The presence of fly eggs, or maggots, or flies will be sufficient evidence that such accumulation of manure has not been sufficiently or properly treated, or protected.

"SECTION 7.—*Establishments Operated for Profit:* Hotels, restaurants, stores, markets, boarding houses, and other establishments operated on a business basis, shall conform to the requirements of the ordinances as enumerated above, unless special exemption is given by the Commissioner of Health. However, no garbage will be removed from any such establishments by the city except to prevent unsanitary conditions, and then only at the expense of the occupant or proprietor. All such establishments shall remove the garbage from their premises and properly dispose of it at least twice a week.

"SECTION 8.—*Removal of Refuse:* Garbage will be removed by the city from private premises where proper receptacles are provided and maintained, and where the occupants comply with this ordinance. Manure shall be removed, by persons who maintain stables, at sufficiently frequent intervals so that the receptacles provided for the manure shall never become full; except that between May 15th and October 15th, no manure shall remain on any premises within the city limits longer than one week, unless special provisions are made for its disposal, with the approval of the Commissioner of Health. Any manure not removed in accordance with this ordinance, by persons who maintain stables, will be removed by the city, and the cost of the removal will be collected from persons failing to comply with this ordinance.

"SECTION 9.—*Scavenging:* It shall be unlawful for any occupant of any building in the city to permit any person to pick over any accumulation of refuse for the purpose of sorting out and recovering any waste materials or for any other purpose."

E. RESULTS IN PRACTICE

Officials in small towns, struggling with the refuse disposal problem, are generally interested in the experience gained in other communities. One particularly useful example of such is at Sewickley, Pa. (1915), described by the superintendent, as follows:

"The Borough has 5000 population, residential in character, with few or no factories. The equipment owned by the City is a two-story brick building enclosing incinerator, costing $8000, and adjoining stable and storage rooms, built at a cost of $2000. The collection system includes two specially made wagons, platforms on long wagon beds with side removable guards, drawn by two horses, with two men, driver and collector.

"The Borough furnishes the cans, of the usual capacity of 11 gal., specially made for the service, and purchased in lots of 200 or more, costing from $1.20 to $1.40 each, depending on the cost of the raw material. They are built to withstand hard usage, and have an average life of three and one-half to four years. They are placed in any location convenient for the householder, and receive all classes of refuse except ashes.

"The collections are made once a week in the residence district, except in the summer when they are made three times in two weeks. Hotels and hospitals have collections twice a week. Each wagon holds seventy-two cans, and they are removed from the house full, each can being replaced with another. Only one wagon is used at a time, the other being loaded with empty cans at the furnace. Four trips a day bring 285 cans, holding approximately 4 tons of garbage and rubbish. An additional ton is brought by grocers, making a daily incineration of 5 tons. The cans are sterilized by hot water and steam before use. The incinerator is operated in two shifts, with one man beginning at 5 A.M. and a second at 2 P.M.

"This method has been in use for eight years and has been very satisfactory. The residents are relieved of any responsibility for the purchase of cans and payment for collection. The Board of Health is satisfied because the system is perfectly sanitary, and the Borough officials feel they have met a necessary obligation at a comparatively low cost.

"The total investment, exclusive of real estate, is distributed as follows:

"Building, driveway, platform, and incinerator	$8,500
Cans, 1285 at $1.20 (average price)	1,542
Stable	2,000
Two horses and harness	700
Two wagons	400
	$13,142

"The average yearly charges for the past four years, to December, 1914, are as follows:

"Removing and collecting garbage (wages of two furnace men, one driver, one collector)	$2,864
Coal and coke	705
Freight, coal, and supplies	405
Horse feed and blacksmithing	524
Repairs	253
Insurance	37
Cans	440
Miscellaneous	96
	$5,324

"On a basis of 5000 population, these figures give an average cost of $1.06 per inhabitant per year. This is raised by $\frac{7}{10}$ of a mill tax on the Borough valuation. These figures make no allowance for interest or sinking fund charges. The appropriation for 1915 was $6000. The cost of collection, requiring half the total items for wages, the horse feed, blacksmithing, and cans, totals $2444, or $0.48 per capita. The incineration charges requiring the remainder of the expenses, are $2880, or $0.58 per inhabitant."

In 1913, Greeley made a report on refuse collection and disposal in Winnetka and Glencoe, Ill., which discusses the refuse disposal methods applicable to villages.

The summary and recommendations of the report are as follows:

"I find the most pressing need of these two villages, as far as refuse disposal is concerned, to be the establishment of a general public system. At the present time, only about 25% of the residents have their garbage and ashes removed. The matter is a private arrangement between these residents and the local scavengers. An expenditure for refuse disposal on as large a scale as required for a crematory should not be undertaken until the collection of refuse has become general in the villages. Otherwise the expense of disposal will be for the few only, and should be paid for by them. The treatment of manure at the stables is inadequate, and should be improved, and the disposal is often irregular. Finally, the miscellaneous dumping of old tin cans is a nuisance, and should cease.

"In view of these conditions and investigations, I make the following six recommendations, upon which I urge you to secure action by the village councils:

"(1) Suitable ordinances for a sanitary code should be drawn up and enforced, governing the house treatment, collection, and final disposal of garbage, ashes, rubbish, and manure, in accordance with the principles outlined above.

"(2) The villages should purchase the necessary equipment and should put into operation a collection system to serve the total population of the two villages for the regular removal of garbage, ashes, and rubbish.

"(3) Arrangements should be made, by purchase or rental, for the use of two areas, one in each village near the western limits, where the garbage can be buried properly and where the combustible rubbish can be burned. Pro-

vision should be made at these areas for the delivery of clean garbage to farmers.

"(4) Stable owners should be informed of a satisfactory method for the stable treatment of manure, and its regular removal should be secured.

"(5) A hydraulic press and hand pump for baling tin cans should be purchased and installed in a small house, and the tin sold for sash weights.

"(6) As a definite solution for the future, the two villages should look forward to a common plant where the rubbish could be picked over and the marketable portion sold, and where the garbage and the unmarketable portion could be burned."

Winnetka and Glencoe are almost entirely residential in character, and are within the Chicago metropolitan district. In 1910 the population of Winnetka was 3168, and of Glencoe, 1899. The population is scattered, and long hauls for small quantities of refuse were to be expected.

Three methods of disposal for garbage were considered: (1) Feeding to hogs, (2) burial in the ground, and (3) incineration with the addition of coal.

Feeding to hogs necessitates the establishment and maintenance of a hog farm. An estimate of the first cost of a farm large enough to handle the quantity of garbage produced in 1920 is given in Chapter VIII. The cost of this farm was estimated at $30,000 for a population of 9000. The revenue from the sale of pork was expected to balance the annual operating costs.

Disposal by burial necessitates the purchase of land. In determining the area required, one acre of land was estimated to be necessary for every $1\frac{1}{3}$ tons of garbage every week day for a year. The first cost of burial fields for the villages was estimated as follows:

	Winnetka	Glencoe
Land, 10 acres at $500	$5000	....
6.5 acres at $400	....	$2600
Attendant's house (10 by 20 ft.) at $2 (say)	500	500
Washing platform	200	200
Water line extension, 1000 ft. at $0.60 per ft.	600	600
Drainage	300	300
Tools and hose	100	100
Planting	400	400
Repairs to road	400	....
Roadways	....	300
	$7500	$5000
Engineering and contingencies	500	500
Total first cost	$8000	$5500

The annual operating cost was estimated to be:

	Winnetka	Glencoe
Attendance—$1\frac{1}{2}$ men at $750 per year (say)	$1200	....
1 man at $750 per year	....	$750
Supplies, water, etc.	200	150
Repairs	100	100
Spring plowing	50	50
	$1550	$1050
Interest, $8000 at $4\frac{1}{2}$%	360	....
5500 at $4\frac{1}{2}$%	....	248
Total annual expenses	$1910	$1298

The estimate of the cost of garbage disposal by incineration was based on an incinerator having a capacity of 15 tons per twenty-four hours. The quantity of coal required was assumed to be 300 lb. per ton of garbage.

The estimate for cost of construction of the incinerator was:

Furnace, complete, including foundation and building	$10,000
Runway, and coal yard	1,000
Water connections	200
Paving in yard	500
Wagon scales and house	1,000
Fence	800
Land, 1 acre	300
Engineering and contingencies	1,500
Total	$18,000

The estimated annual cost of operation was:

Labor, one man, whole time	$ 900
one man, half time	450
Fuel, 165 tons at $4 per ton	660
Water	100
Repairs and supplies	490
Total	$2,600
Interest, $18,000 at $4\frac{1}{2}$%	810
Depreciation	670
Total annual cost	$4,080

The method of feeding to hogs was recommended on account of the expected revenue therefrom.

It was planned to dispose of the ashes by fill, as there were many low spots available for this purpose, and also new roadways building.

The method of disposing of the rubbish was by sorting out salable material and burying or burning the remainder. Of the marketable material, the paper was to be shipped to one buyer, the glass to another, and the scrap iron to a third. Carload lots would be necessary. The equipment would have to be housed in a two-story building.

This program has been partly developed. A comprehensive ordinance has been passed, and kitchen cards distributed. Canvas-covered garbage carts (capacity, 1.5 cu. yd.) have been purchased, also 10-cu. yd. rubbish wagons and 3-cu. yd. ash wagons for bottom-dumping. Free collections of garbage, ashes, and rubbish are made at comparatively infrequent intervals, but planned so as to fall within the annual appropriations allowed by law. More frequent service is furnished to those who wish it, on payment of 25 cents per month for each room in the house. This arrangement keeps the town clean, obviates the need for annual clean-up weeks, and provides good service those who produce the larger quantities of refuse and are able to pay for such service. During the winter, when the quantity of garbage is small, two garbage containers are attached to the rear of the ash wagons, thus reducing the cost of collection.

F. SUMMARY AND CONCLUSIONS

The refuse problem in small communities should receive more consideration than is usually given to it, if cleanliness and sanitation are to be satisfactory. Usually and properly, the water supply is of first importance, and secondly the sewerage. After these are provided, the refuse problem calls for community attention. Funds are generally not abundant, and progressive solutions are desired, with the greatest utilization of all existing advantages.

To prevent a waste of invested funds, it is economical, even for small communities, to have experienced advice on the best procedure. It may not be practicable to build works at once, but only in part, leaving the future to make extensions and enlargements. This would provide a plan which later would be along the lines of the best sanitation and least cost, and prevent a possible abandonment of the works built, or, present the introduction, perhaps, of undesirable

features. In all cases it is important to secure community control, but only after a most careful examination has been made into the specific characteristics of the local problem.

It is important to adjust all procedures to the general and local conditions, and to know the quantities and kinds of refuse materials, because these determine the choice of the method of disposal. A closer knowledge of the quantities and character of the materials should extend, if possible, over a period of at least one year, in order to embrace the different seasonal variations. Particularly, probable extremes should be known, as the yearly average production may differ much from the maximum and minimum rates; and the capacity of the works, if based on an average, might fall quite short of the requirement.

It is important, further, to obtain accurate measurements and data covering the house treatment, collection, possible transportation, and final disposition, so that they will be available at any time when further improvements become economical and desirable.

The essentials of refuse collection and treatment in small communities, therefore, may be stated briefly as follows:

The house treatment should be regulated by ordinances, so that efficiency and economy for the community as well as the occupants will result.

The collection should be as frequent as required by the local conditions and the selected method of disposal, and it should be done in a manner to prevent any objectionable features in the delivery of the materials. It may be done by force account under an efficient superintendent, or by contract under sufficiently detailed specifications and supervision.

The selection of the final disposal system should be made only after a careful study. In general, separate collections of the different classes of the refuse will be preferable for small communities.

Garbage may be disposed of by feeding to hogs, or, if this is not feasible, by shallow burial or incineration.

Rubbish may have parts of it picked out by licensed scavengers, and this privilege be sold at a slight profit. The remainder should be incinerated. The latter can be done in wire baskets or barrels at the houses, or in small furnaces for institutions. If the community undertakes the disposal, it should be done in amply large furnaces. When burning refuse, regulations should be followed carefully, in order to avoid offensive odors. It is practicable and economical in a number of towns to incinerate a mixture of rubbish with garbage, without ashes, and in some houses a small quantity of garbage in the kitchen stove, preferably after desiccation in the flue. It is not

advisable to dump rubbish on any ground that is expected to be used for any other purpose within a few years.

Under proper regulations, street sweepings and ashes in small towns may be generally best disposed of by dumping in low places.

Stable manure should usually be disposed of for fertilizing neighboring fields, rarely by filling in low areas.

Night-soil is best buried in shallow trenches, or used as a fertilizer on fields; and dead animals, unless collected for rendering purposes, should be buried in a suitable material.

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